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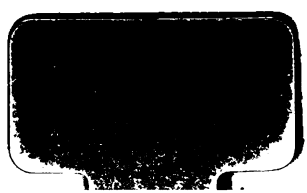

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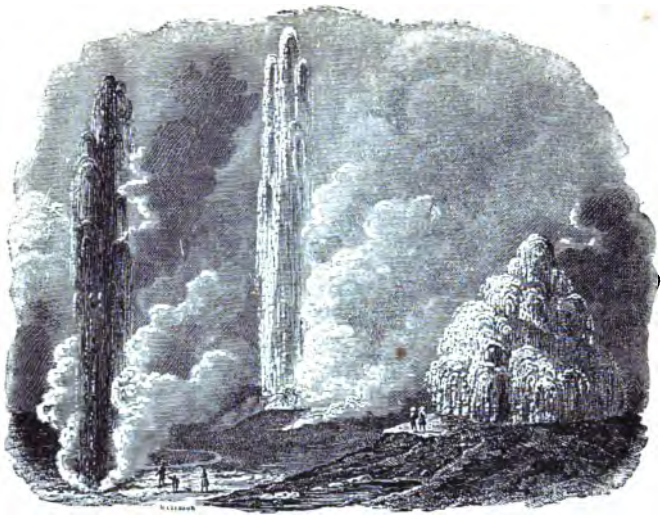

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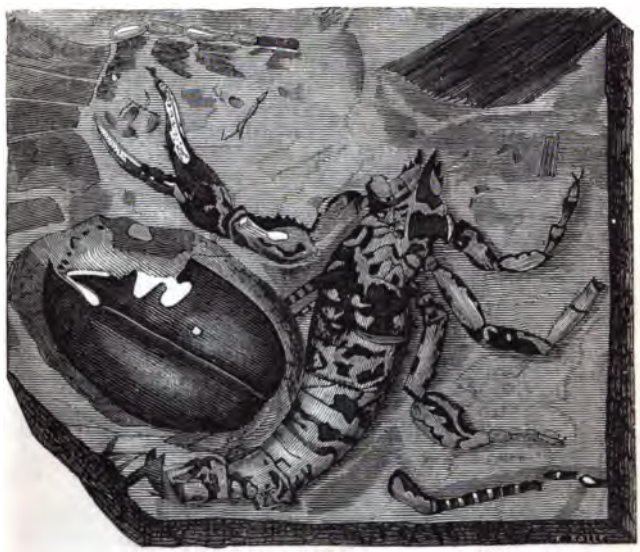

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BY

DIONYSIUS LARDNER, D.C.L.,
Formerly Professor of Natural Philosophy and Astronomy in University College, London.

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ERRATA.

Pre-Adamite Earth, page 85, paragraph 362, line 2, *for* "160," *read* "163;" page 86, line 10, *for* "Equitaceæ," *read* "Equisetaceæ."

LISBON AFTER THE EARTHQUAKE OF 1755, REDUCED FROM AN ENGRAVING, DATED 1756, IN THE IMPERIAL LIBRARY AT PARIS.

EARTHQUAKES AND VOLCANOES.

CHAPTER I.

1. Science tends to the discovery of general laws—admits no accidental phenomena.—2. Atmospheric phenomena neither uncertain nor accidental.—3. Physical subterranean agencies.—4. Convulsions incidental to the solid shell of the earth.—5. Increase of temperature at increasing depths.—6. Central parts in a state of fusion.—7. Depth at which this liquid state commences.—8. Proportional thickness of the solid shell.—9. Surface of the earth subject to frequent convulsions from the reaction of the internal fluid matter on the solid shell.—10. Geological evidences of this.—11. Physical causes of earthquakes and volcanoes.—12. Undulations of surface produced by the internal fluid.—13. Their effects on buildings and other objects.—14. Vertical and oscillatory motions.—15. Undulations propagated

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1. It is the tendency of undisciplined minds to refer all unusual and occasional phenomena to local and accidental causes, and, mistaking trivial and unimportant differences for essential distinctions, to ascribe to very different physical agencies what are only various effects proceeding from the operation of a single principle. The tendency of science is the reverse. It ignores accident in nature. It admits no contingencies. The Architect of the universe operates by fixed and general laws, the results of which are uniform and regular. The apparent uncertainty of some natural phenomena arises merely from our imperfect knowledge of the laws which govern them. Before the science of astronomy had reached a certain degree of advancement, solar and lunar eclipses were regarded as preternatural manifestations, during which the common laws of nature were suspended, and as the forerunners of terrible calamities to the human race. Now that the laws which govern the motions of the heavenly bodies are known, these phenomena have lost their terrors. They are no longer regarded as either preternatural, uncertain, or accidental. They are, on the contrary, as regular, periodical, and certain as the seasons, or the returns of light and darkness; and the times of their occurrence, and all the circumstances attending them, are predicted with the greatest conceivable certainty and the last degree of precision.

2. Nothing is more usual than to apply the term "uncertain" to the weather, yet nothing can be more absurd. The causes which govern its phenomena being physical agencies independent of the will or interference of any being, save of Him "who rules the storm," are as fixed and as certain in their operation, and as regular in the production of their effects, as those which maintain and regulate the motions of the solar system. The moment of the rising or setting of the sun on any given day of the ensuing year, is, therefore, *in the nature of things*, not more certain than

the atmospheric phenomena which will take place on that day. The doubt and uncertainty which attend these events belong altogether to our anticipations of them, and not to the things themselves. If our knowledge of meteorology were as advanced as our knowledge of astronomy, we should be in a condition to declare the time, duration, and intensity of every shower, which shall fall during the ensuing year, with as much certainty and precision as we are able to fortel the rising, setting, and southing of the sun and moon, or the rise and fall of the tides of the ocean.

3. If our knowledge of the laws which govern the movements of the aërial ocean which floats above the crust of the earth be obscure and imperfect, it is infinitely more so of those which rule the matter which lies below that crust. Yet what various and apparently different and unconnected phenomena are governed by these undiscovered laws, which, through ignorance of them, have been regarded as arising from local, accidental, and totally independent and different agencies. Earthquakes, volcanic eruptions, the production and submersion of islands, the issue of gases such as sulphurous and carbonic acid from fissures in the earth, hot springs, eruptions of warm mud, the increase of temperature at increasing depths, the origin of mountain chains, such as the Andes, the Pyrenees, the Alps, and the Himalaya, the alternate elevation and submersion of vast continents, the variations of the configuration of the land, and the distribution of the waters on the surface of the globe, all these so apparently different phenomena, it has been the triumph of science to trace to a common origin, the reaction of the matter confined within the earth against its external shell.

4. It is our present purpose briefly to explain the physical conditions out of which these stupendous phenomena arise, and to describe the characters and circumstances which attend them. With this view, it will be necessary first to state what is known, either by observation or inference, respecting the condition of that part of the earth included within the solid shell, the external surface of which is the habitation of the human race, and other organised tribes, and to explain generally what have been at past epochs and at the present time the chief effects produced by the reaction of the matter thus confined upon the crust which encloses it.

When it is considered that the actual distance of the surface from the centre, or the length of the terrestrial radius, is more than twenty millions of feet, and that the utmost depth to which we have been able to descend in boring or mining operations has not much exceeded two thousand feet, that is the ten-thousandth part of the entire radius, it will be apparent that the data

supplied by so scanty a range of observation must be very limited. Less direct sources of observation, though not less certain and precise, have, however, been opened by the researches of geologists, who have shown that the crust of the earth fractured by eruptions produced by forces acting from the interior outwards has been exposed to view, so that the condition of the external shell, to a depth of about forty thousand feet, or the five-hundredth part of the entire distance from the surface to the centre, can be ascertained.

5. From what has been explained in former numbers of this series, in which the subject of terrestrial heat has been considered, it will be seen that extended and general thermometric observations made in mines and other deep excavations, and on the temperature of water rising in Artesian wells, prove that in descending to greater and greater depths into the crust of the earth, there is a constant and regular increase of temperature at the rate of about one thermometric degree for every fifty feet of depth, or what is nearly the same, an increase at the rate of 100° per mile.

6. Now supposing this law of increase to continue without interruption downwards, it would follow that at the depth of forty miles, or the hundredth part of the distance from the surface to the centre, a temperature of 4000° prevails. It is certain that no part of the matter composing the crust of the earth could remain solid at such a temperature, being higher than those at which the most refractory bodies are fused.

7. No great degree of precision in the numerical data on which this calculation is based is necessary to establish the conclusion to which it leads. Whatever be the exact rate at which the temperature is augmented in descending, it is beyond all doubt that at a depth of thirty or forty miles it must be such as to reduce to the state of an incandescent liquid the most refractory bodies which enter into the composition of the earth.

This liquid fire must extend to the very centre of the globe, and from the well understood properties of fluidity, it may be considered certain that an uniform temperature is maintained throughout the liquid mass thus enclosed within the solid spheroidal shell.

Now let us pause for a moment to consider the consequences to which this leads, and to contemplate the spectacle which it offers of the condition of our terrestrial dwelling.

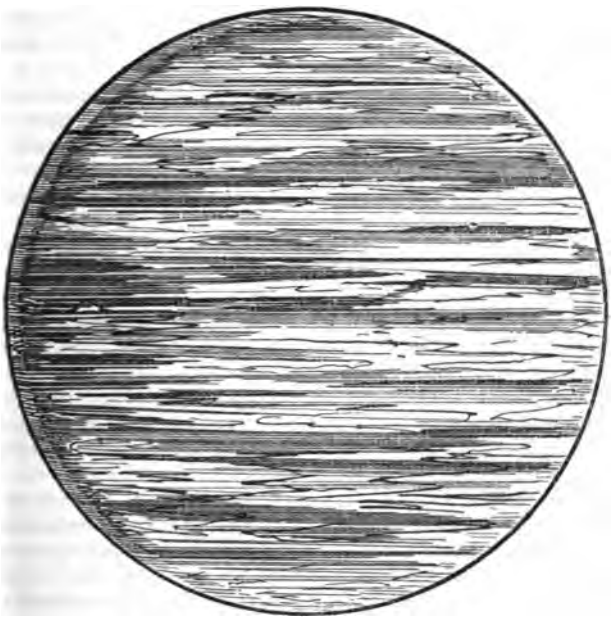
8. Let us take the extreme estimate of forty miles as the depth below which the matter composing the earth is completely liquified. This depth is the one-hundredth part of the terrestrial radius.

We are then to regard the earth as a spherical shell of solid matter filled with liquid fire. The thickness of this shell being in

the proportion to its diameter just stated, it will be represented by the black circle surrounding fig. 1.

If the egg of a fowl or an ostrich be imagined to represent the earth, its shell would be much too thick to represent its solid crust!

Fig. 1.



It is no rhetorical exaggeration, then, to affirm that the globe we live on is a stupendous but very thin bombshell charged with liquid fire! If such be the case, it may naturally be asked how it happens that so thin a crust, supported on so mobile a fluid, can maintain that general state of stability and equilibrium which characterises the surface of the earth, so that it is referred to in times ancient and modern as the type of all that is most solid and durable?

9. To this it may be answered that many phenomena with which mankind in certain localities is only too familiar, and which are known to all by authentic contemporary reports and historical records, prove that this imputed stability cannot be admitted without most serious qualifications and exceptions. Not a year passes that earthquakes are not reported in various parts of the

earth. Not a century passes that these terrible phenomena are not occasionally developed with such an energy and extent that vast tracts of country are laid waste, cities and towns destroyed, and thousands of human beings buried beneath their ruins. Volcanic eruptions are permanent indications of subterranean agencies, modifying more or less the surface. Torrents of lava and clouds of ashes ejected from them cover surrounding regions, and sometimes entomb entire cities. The solid bottom of the ocean is occasionally heaved upwards by a force from below, so as to form new islands, which sometimes subsiding are again submerged. These and countless other phenomena show that the crust of the globe is not so solid and unchangeable as it is generally assumed to be.

10. But if, instead of confining our view to that comparatively brief interval in the life of the earth limited by the existence of the human race, and the other organised tribes animal and vegetable, which now prevail upon it, we extend our enquiries over those periods of the past, far more vast, with which the discoveries of astronomers and geologists have made us to some extent familiar, we shall find monuments and records of physical changes produced by eruptive forces emanating from the central parts, on a scale so prodigious, that compared with them, the most devastating earthquakes and volcanic eruptions are utterly insignificant. The central fluid matter pressing unequally on its confining shell, has at various times cracked it in different directions, and the molten mineral matter, issuing from the fissures, and gradually cooling, taking first a pasty and semifluid consistency, and afterwards solidifying, has formed mountain chains over the fissures. Such has been the operation by which the vast ridges of the Andes, which traverse the new continent from north to south, and those of the Alps and Himalaya, which traverse the old continents from east to west, have been formed.

11. Postponing, however, for the present all notice of those physical revolutions of which the date is prior to the creation of the present inhabitants of the earth, we shall limit our observations to the circumstances which produce and attend the principal convulsions of nature which have manifested themselves in historical times, and which must be traced to the reaction of the interior fiery fluid upon the thin solid shell of the earth.

That fluid, like the waters of the ocean, is subject to undulation. If its undulations be so limited in their play that the materials of which the terrestrial shell is formed have sufficient elasticity to yield to their pressure without being fractured, they will produce on the exterior surface of that shell corresponding undulations by which all bodies placed upon its surface must be

affected, as a floating body is by the waves of the ocean. If the height of the waves of the subterranean fluid be greater than the elasticity of the solid shell which confines them can bear, that shell must be fractured to a greater or less extent, and through the openings thus produced in it, the internal matter, in a state of igneous fusion, may issue, producing volcanic phenomena. Or in fine, the fracture may be only external, in which case the consequences will be limited to local derangement and disturbance of the surface.

Let us first consider the case in which an undulation is propagated to the surface without fracture.

12. The part of the surface of the earth thus affected, and all bodies placed upon it, suffer in this case the same sort of disturbance and dislocation as does a ship floating on water upon which a system of waves is formed. The waves have a progressive motion in some certain direction, passing successively under the ship, which is alternately raised to the crest and lowered to the hollow of each successive wave as it passes. Neither the water nor the ship partakes of this progressive motion. If they did no alternate rise and fall would take place; the ship once placed on the crest of a wave would be carried forward by the water on which it floats, and would still remain on the crest of the same wave, a circumstance which never takes place. In the same manner exactly the undulations imparted to the surface of the earth by the fluid confined within it, have a certain progressive motion which causes every part of the surface over which they pass, alternately to rise and fall, through a height equal to the difference of the levels of the crest and hollow of the wave.

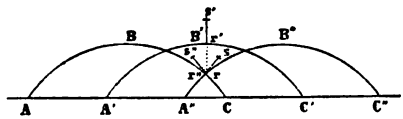
13. But besides this, another effect of much importance is produced upon solid structures, which are placed, as buildings are, in a position perpendicular to the level surface of the ground. That surface when it is affected by the wave, ceases to be level. As the wave passes it, it is first inclined in one direction, and after being raised to the summit of the wave it is inclined in the opposite direction. Any solid structure, having a vertical position, would, therefore, while the wave passes, be inclined from the vertical, first to the right, and then to the left, according as it is successively at one side or other of the wave.

Such superficial undulation of the ground, would therefore produce a twofold displacement of all such objects; first an alternate motion upwards and downwards in the vertical direction, and secondly, a sort of rocking or oscillating motion like that of a pendulum, leaning alternately right and left of its true vertical position.

This will be better understood by reference to fig. 2, in which

three successive positions of the wave are represented by A B C, A′ B′ C′, and A″ B″ C″. A building or other object in a position perpendicular to the ground is represented at *r s* on the slope of the wave where it leans from the vertical to the right. When the wave has advanced to the position A′ B′ C′, the foot of the building

Fig. 2.



is raised to the crest of the wave at *r′*, and the building, *r′ s′*, is then vertical, having in the interval been gradually raised from its inclined direction. When the wave has progressed to A″ B″ C″, the foot of the building has been again lowered to its first position, but being now on the slope, A″ B″, it will be inclined to the left of the vertical, as represented at *r″ s″*.

14. Thus by the undulations passing successively under it, such a building will be alternately raised and lowered through a certain vertical height, and at the same time *rocked* right and left through a certain angle of vibration.

The undulations which produce earthquakes are sometimes rectilinear and propagated in parallel lines and in a single direction. In other cases they form concentric circles, and are propagated from a certain central point, like the waves produced on the surface of still water round the point at which a pebble is dropped into it.

The angle through which objects will be deflected from the perpendicular in the rocking motion imparted to them, will depend on the angle of the slope of the wave, and the latter will depend on the proportion which the height of the undulation bears to its amplitude. The less the height, and the greater the amplitude, the less will be the deflection from the perpendicular. In the cases of many earthquakes, this deflection is so small, that the cohesion of the materials of building is generally sufficient to prevent them from falling notwithstanding their deflection.

That a building may stand, though inclined considerably from the perpendicular, is proved by examples which occur in almost every city. The leaning towers of Pisa and Bologna have stood for seven hundred years.

The effect of the alternate motion, upwards and downwards in the vertical direction, must depend more upon the rapidity of the alternation than upon the range of the elevation and depression. It is easily conceivable that the ground may be *slowly* raised and

depressed through a very considerable height or depth, without producing any superficial derangement, but if such elevation and depression take place with much rapidity, great disturbance must ensue.

15. Humboldt, who has been personal witness of a considerable number of these phenomena, and has elaborately investigated the recorded effects of the most remarkable of them, says that the undulations are propagated chiefly in parallel lines, and with a progressive velocity of from twenty to thirty miles per minute. He observes that the cases in which the waves issue from a centre of undulation, and are propagated in circles around it, are more rare, and that when it takes place, the height of the waves diminish as their distance from the common centre increases.

In general, the undulations are inconsiderable in their vertical height and velocity of oscillation, so that in places affected by them, the strength of buildings is sufficient to resist their effects, and we constantly hear of slight shocks of earthquakes being sensible, which are attended with no injurious consequences. Bells are sometimes thus rung, and furniture and other loose objects more or less displaced without other more serious consequences.

16. The vertical shock however, in places more subject to these visitations, is sometimes attended with far more grave effects. In the case of the earthquake, by which the town of Riobamba, at the foot of Chimborazo, was destroyed in 1797, the bodies of many of the inhabitants were hurled to a height of several hundred feet, and thrown upon the hill of La Cullca, beyond the small river Lican.

17. Humboldt cites examples of the circular propagation of terrestrial undulations at the Holy Sea, or Lake Baikal, in Siberia (between lat. 51° and 55°, and long. 103° and 110° E.), and in the Celestial Mountains, or Thian-schan, in Chinese Turkestan, (between lat. 42° and 43°, and long. 80° and 90° E.) The intermediate region is subject to the double influence of the circular undulations propagated from these two centres, and Humboldt ingeniously explains the freedom from earthquakes of a certain intermediate tract between two such centres of undulation, by the principle of interference which plays so important a part in optics and acoustics. He supposes that along such a tract the crests of the waves of one system coincide with the hollows of those of the other, so that the ground being just as much elevated by the one as it is depressed by the other, remains undisturbed, while the country at either side is agitated, and perhaps devastated, by the shocks.

18. In certain cases, the motion imparted to the surface is not merely that of undulation properly so called, which, as already

explained, can only produce vertical and oscillating motions, it has been found, in some cases, that the ground has been affected by an horizontal as well as vertical displacement. In some cases also a gyratory movement of the ground has been observed, so that after the shock, the direction of the walls of buildings, and the relative bearings of fixed objects, such as buildings, trees, and the directions of hills and valleys have been changed.

19. Humboldt states, that although the undulations of the surface of the ground, which take place in earthquakes, have been ascertained with some degree of precision, their periods of alternation have not been so well observed. In the city of Quito, which stands at the foot of the volcano of Rucu-Pichincha, at an elevation of nearly 10000 feet above the level of the sea, he often felt strong shocks of an earthquake at night. Yet the buildings of the city, including many lofty churches, fine cupolas, and houses consisting of many stories, were very rarely injured by them, although much slighter shocks damaged lower buildings on the Peruvian plains.

The natives of the country, who are accustomed to the phenomena, many hundred earthquakes occurring during a single generation, explain this difference by the greater or less rapidity of the horizontal oscillation, which, according to their experience, is far more destructive than the vertical or rocking motion produced by regular undulation.

20. The earthquakes which produce a gyratory motion of the ground are the most destructive, and happily also the most rare. After the earthquake which destroyed Riobamba in 1797, and that which took place in Calabria in 1783, walls were changed in their direction without being thrown down, rows of trees, which were previously strait and parallel, were, after the shock, in different directions, and even in curved rows. Fields were changed in their relative positions, those in which two different crops were growing having interchanged places.

21. Humboldt was shown among the ruins of Riobamba a place where the entire furniture and contents of a certain house were found buried under the remains of another. Numerous cases occurred in which heavy articles of furniture were transported several hundred yards from their original position, so that questions of ownership were raised and brought before the courts of justice.

In this case the ground, rent in various places, was affected at once by vertical and horizontal oscillations, so that while one part was heaved upwards another adjacent to it was sunk downwards and transferred horizontally under the former. Such tossing and agitation of the surface presents a striking resemblance to the

irregular and tumultuous agitation of the surface of the sea after a storm, and must arise from such a condition prevailing for the moment in the igneous ocean upon which the solid crust of the earth rests.

22. A popular impression prevails that earthquakes are preceded by peculiar atmospheric phenomena, such as a profound stillness of the air, a suffocating and oppressive heat, and a misty horizon. Exact and extensive observations made in various countries, and for long periods of time, have proved that this is without any foundation in fact. Humboldt states not only as the result of his own experience, but as that of those who have lived for many years in regions where earthquakes are frequent, that they take place indifferently in all weathers and in all states of the atmosphere. He experienced them himself in clear and fair as well as in rainy weather, and as often in a fresh east wind, or in a storm, as in a calm. He observed no disturbance or exceptional condition in the magnetic needle, the barometer or thermometer, either on their approach or during their continuance. His own observations within the tropics, and those of Adolphe Erman during the earthquake of the 8th of March, 1829, at Irkutsk, near Lake Baikal, lat. 53°, were in this respect in complete accordance.

Nevertheless, the subterranean convulsion appears to have been in some cases attended with atmospheric effects, which would indicate some connection between the phenomena and the electric state of the surface and of the atmosphere. Thus, for example, during the long-continued trembling of the ground in the Piedmontese valleys of Pelis and Clusson, considerable variations of the electric tension of the atmosphere were observed, which could not have arisen from any storm, the sky being at the time quite serene and unclouded.

23. From some statistical results, it would seem that there are grounds for supposing a connection between the prevalence of earthquakes and the season of the year. Numerical data, collected with much care, by MM. de Hoff, Merian, and Hoffmann, indicate the greatest frequency of these phenomena at the epochs of the equinoxes.

24. It is a fact not unworthy of remark, that notwithstanding the backward state of physical science generally among the ancients, and their total ignorance of the modern science of geology, the true physical cause of earthquakes was indicated in unequivocal terms by Pliny,* who denominated them "Subterranean storms;" and Seneca† gave the germ of all that was known about their causes until a very recent date.

* Pliny, ii., 79.

† Nat. Quæst, vi., 4—31.

25. Earthquakes are often attended, though not at all, as is commonly supposed, preceded by awful subterranean sounds. These noises, however, appear to have no relation whatever to the violence of the shock. Some of the most tremendous of these convulsions have, on the contrary, been unaccompanied by any noise whatever. This was the case with the great earthquake of Riobamba already mentioned, one of the most terrible catastrophes of its class which has been recorded in the physical history of the globe.

The noises which are heard most commonly occur after the shock, and seldom at the place where the earthquake has the greatest violence. In the case of the earthquake of which Tacunga and Hambato were the centre and points of greatest action, no noise was heard at these places, but violent subterraneous detonations were heard at Quito, which is fifty-five miles, and at Ibarra, about one hundred miles distant from those points, at twenty minutes after the shock.

The subterranean thunder, if it may be so called, is sometimes heard at places situate beyond the limits of the shocks. Thus in the case of the violent earthquake which occurred at Lima and Callao, on 28th October, 1746, a noise resembling a clap of subterranean thunder was heard at Truxillo, where no shock whatever was felt, nor even the least trembling of the ground.

Sometimes the subterranean thunder is heard after the shocks have ceased. The great earthquake which occurred on 16th November, 1827, in New Grenada, and was described by Boussingault is an example of this. Some time after the cessation of the shocks, subterranean detonations were heard at regular intervals of half a minute along the whole Cauca valley.

26. The character of the noise attending earthquakes has differed greatly in different cases. Sometimes it has been a rolling sound like that of thunder, or the discharges of cannon in rapid succession. Sometimes it is described as resembling the clanking of chains. At Quito it is often sudden, like a near thunder-clap, and sometimes it is clear and ringing like the clashing of glass, as if enormous masses of vitrified matter were shattered in subterranean caverns.

27. Owing to the fact that solid bodies are good conductors of sound, the sonorous undulations being propagated through them with a velocity ten or twelve times greater than through the atmosphere, the subterranean noise developed in these convulsions may be heard at great distances from the seat of the agency which produces it. During a violent eruption of the volcano of St. Vincent, one of the smaller West India Islands, and while a prodigious torrent of lava issued from it, a loud noise resembling

thunder unaccompanied by any trembling of the ground, was heard at the distance of 632 miles to the south-west of the crater on the plains of Calaboso, and on the banks of the river Apure, one of the tributaries of the Orinoco. This noise was audible over an area of nearly 50000 square miles. So far as distance is concerned, this was as if a noise attending an irruption of Vesuvius were heard at London.

28. During the great eruption of Cotopaxi, one of the most lofty peaks of the Andes, subterranean sounds like discharges of artillery were heard at Honda, on the Magdalena river. This is the more remarkable, inasmuch as the crater of Cotopaxi is not only 18000 feet above the level of Honda, and the distance measured in a direct line between the two points is 463 miles, but vast mountain masses such as Quito, Pasto, and Popayan, as well as innumerable valleys and ravines are interposed between them. The sound was therefore evidently in this case propagated through the solid crust of the earth from a great depth, and not through the air.

Another striking example of the propagation of sound from the depths of the earth to great distances through its crust was presented in the case of the violent earthquake which occurred in New Grenada, in 1835. On that occasion, subterranean thunder was heard at Popayan, Bogota, Santa Martha, and Caraccas, and also in Hayti, in Jamaica, and on the shores of Lake Nicaragua. At Caraccas the thunder continued without any sensible trembling of the ground for seven hours.

It would appear that in some cases the solid telluric shell is strong enough to resist the undulations of the subterranean igneous fluid while it transmits the sonorous vibrations. It is difficult to convey an adequate idea of the impression which these terrible sounds, issuing from the depths of the earth, produce, when they are not attended by any dynamical or other phenomena. It is as if a preternatural voice coming from below addressed the entire population. The listener waits after each roll of the sound in an agony of suspense for what may follow.

29. One of the most remarkable examples of these subterraneous sounds unaccompanied by any disturbance of the surface of the ground, was that which occurred in the great mining regions of Mexico, in 1784, and which is known in that country as the *Bramidos subterraneos* (subterraneous roaring) of Guanaxuato.*

* Humboldt, Essai Polit. sur la Nouv. Esp., vol. i., p. 303. Cosmos, Trans. vol. i., p. 196, and note 187.

Guanaxuato is the capital town of the mining district of that name, situate in the Sierra de Santa Rosa, at 160 miles north-west of Mexico, and at an elevation of 6000 feet above the level of the sea. It is irregularly built on mountain declivities, and is surrounded by deep shafts, through which the produce of the rich gold and silver mines is brought to the surface. More than an hundred of these shafts are sunk within a radius of fifteen miles round the town. There is no active volcano in the neighbourhood.

The subterranean sounds were first heard at midnight on the 9th January, 1784, and they continued without intermission for more than a month. A circumstantial description of the progress of the phenomenon was obtained by Humboldt on the spot, from the reports of numerous witnesses, and from the documents of the municipality, which he was allowed to copy.

From the 13th to the 16th it seemed as if a rolling thunder alternately with loud and sharp thunder-claps issued from storm clouds beneath the foundation of the town. These sounds, which increased from the beginning by slow degrees, until they attained their greatest loudness and violence, ceased by the same slow degrees. It was remarked, however, that the range of the phenomena was not considerable, the sounds being heard only in the mountainous part of the Sierra, from the Cuesta de los Aquilares to the north of Santa Rosa. No sounds were heard in a basaltic district at a few miles distance, nor in the detached portions of the Sierra, twenty-four to twenty-eight miles north-west of Guanaxuato. Not only was the surface of the ground free from the least trembling or other movement, but none was felt in the workings of the mines, which passed in all directions at great depths below the surface.

30. When this extraordinary phenomenon commenced, the inhabitants of the place were seized with uncontrollable terror, and with a spontaneous movement began to take flight. This was at first resisted by measures of extraordinary severity on the part of the authorities. Flight from the city was punished with a fine of 1000 piastres, or two months imprisonment, and the militia were ordered to arrest and bring back the fugitives. One of the most curious circumstances attending the commencement of the disturbance was a proclamation issued by the magistracy, declaring "that in their wisdom they would be well aware of the approach of real danger, and that whenever it might arise they would give notice to the inhabitants to fly, but that as yet it would be sufficient to continue the processions," meaning no doubt some religious ceremonies.

The inhabitants of the surrounding table lands being prevented

by their fright from bringing supplies into the markets of the town, a famine commenced, and the power of the authorities being at length overborne, a general flight ensued. Nearly the whole population deserted the town, in which large masses of the precious metals, the produce of the surrounding mines, had been stored. Bands of plunderers lingered to seize this treasure. After a while the inhabitants being familiarised with the continuance of the subterraneous thunder, unaccompanied by any other symptoms of earthquake, the more courageous returned to the town and fought with the robbers in defence of their property.

In no part of the mountainous regions of Mexico was anything of this kind ever before known or heard of, nor has it ever recurred since. Thus it would appear, that as chasms in the inferior parts of the crust of the earth are opened or closed, the sound produced by the agitation of the igneous ocean, which roars beneath it, is propagated or intercepted in different directions and at different times.

31. It would be a great mistake to assume that earthquakes are always merely local phenomena of very limited range. On the contrary, they have in some cases been manifested over a large portion of the surface of the globe. The great earthquake by which Lisbon was destroyed on the 1st November, 1755, was felt over the whole extent of Europe, from the Alps to the coast of Sweden, over Northern Germany and the shores of the Baltic, across the Atlantic to the West Indies, where the shocks were sensible in the islands of Barbadoes, Martinique, and Antigua, and across the continent of North America to the great northern lakes.

Distant fountains were interrupted in their flow. Thus the hot springs of Töplitz were first dried up but soon reappeared, sending up unusual quantities of water of an ochreous colour.*

32. That the solid surface of the bottom of the ocean shared in the general undulation manifested over so great an extent of the continents on this occasion could not be doubted, if no other evidence of it existed save the transmission of the undulation across the Atlantic. But we have more direct evidence of this in the sudden changes of elevation of the water of the ocean itself. At Cadiz the sea rose above sixty feet, and in the islands of Barbadoes, Martinique, and Antigua, where the normal rise of the tide does not much exceed two feet, the water suddenly rose

* The fact that earthquakes had the effect of interrupting the flow of springs was known to the ancients, and is noticed by Demetrius of Calatia.

twenty feet, and was moreover discoloured, having the blackness of ink.

33. During the earthquake the water retired from the harbour at Lisbon, leaving the bar uncovered and dry, but it soon returned, rushing in enormous volumes, so as to rise in some places to the height of sixty feet. The shores were everywhere inundated, and the seaport of St. Eubal's, about twenty miles south of Lisbon, was submerged and totally disappeared.

The records of these convulsions of the earth supply many examples showing that the bottom of the sea has shared the perturbations of the land. In the case of the great earthquake which desolated Peru, in 1746, the Pacific rushed upon the coast with irresistible fury, destroyed several seaports, carrying the vessels which floated in them to great distances up the country, and submerging a large tract of land near Callao, so as to convert it into a permanent bay.

VIEW OF NAPLES AND VESUVIUS.

EARTHQUAKES AND VOLCANOES.

CHAPTER II.

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rises.—51. Also certain gases—Artesian fire-wells.—52. Carbonic acid—its effects in former states of the globe—origin of coal beds.—53. And marbles.—54. Mud volcanoes.—55. Those of remote origin.—56. Progressive development.—57. Formation of dome-shaped mountains.—58. Crater of elevation.—59. Active volcanoes.—60. Successive stages of their formation.—61. Not uniformly or permanently active.—62. Intervals of activity and repose.—63. Dependent on the height.—64. Stromboli.—65. Guacamayo.—66. Volcanoes of the Andes.—67. Exceptions explained.—68. Eruptions often lateral.—69. Groups of small cones.—70. Remarkable spectacle of Cotopaxi.—71. View of an active crater.—72. Remarkable permanence of the form of craters.—73. Effects of snow-capped cones.—74. Cause of the fiery appearance of ejected matter.—75. Islands of volcanic origin.—76. Volcanic theories.

34. A REMARKABLE submarine earthquake occurred in the Gulf of Mexico in 1780, during which a mass of water was carried against the western coast of the island of Jamaica, which in an instant submerged the entire town of Savannah la Mar. Not a building nor living thing escaped this prodigious irruption of water.

The same island underwent still more extensive devastation from an earthquake which occurred there in 1692. Three-fourths of Port Royal, the capital of the island at that time, suddenly sunk down, and with all its inhabitants was submerged by the sea. Large warehouses which stood upon the quays were submerged to such a depth, that their roofs were from 20 to 40 feet below the surface of the water. The subsidence was so evenly vertical and so free from any lateral displacement or rocking motion, that many of the houses sunk without falling; so that after the catastrophe the chimney-tops of some of them were seen, as well as the topmasts of ships wrecked in the harbour, projecting from the surface of the water. A vessel of war which had been under repair in one of the docks was transported over several of the submerged buildings, and finally rested upon one of the sunken houses, breaking through the roof.

In the first shock of this earthquake a tract of the adjacent country of the extent of above a thousand acres was instantaneously submerged.

35. It has been calculated that in the great earthquake of Lisbon, a portion of the earth's surface more than four times the area of Europe was affected by the undulation, without taking into account any part of the submarine disturbances which attended it.

36. As examples of shocks and tremblings of the ground which have continued from hour to hour for several successive months, Humboldt produces the following examples, all of which took place at great distances from any active volcano. On the eastern slope

of Mount Cenis, at Fenestrelles and Pignerol, the phenomena commenced in April, 1808. The liquid contained in full glasses exhibited a constant agitation and trembling. In the United States, at New Madrid, and Little Prairie, north of Cincinnati, the trembling commenced in December, 1811, and continued through the winter of 1812. In the Pachalik of Aleppo the shocks continued during the months of August and September, 1822.

37. Since the perturbation of the crust of the earth is produced by the agitation of the subjacent igneous ocean, it is no otherwise dependent on the nature of the matter which forms that crust than so far as such matter may be more or less susceptible of receiving and transmitting the undulations. Accordingly we find earthquakes occurring in every sort of soil, and strata from the loose alluvial soil of Holland to superficial strata of granite.

38. It is, however, certain that the mechanical structure of certain strata are such as to arrest the undulation. Thus, when an earthquake shock, or wave as we shall call it, is propagated along a line of coast, or along the foot of a mountain chain, certain points of interruption have been observed, over which the wave passes without producing any disturbance, resuming its character beyond their limits. Such tracts are well known, and have preserved their immunity from the shocks which affect the country at either side of them for centuries. It appears that the undulation of the subterranean fluid passes under these without affecting them. The Peruvians, who are of all people the most familiar with earthquakes, call these tracts *bridges*.

39. It does not at all follow, however, that because the superficial strata are not affected by the undulation, the inferior strata are exempt from it. At the beginning of the present century earthquake shocks were felt with such violence in the workings of the deep silver mines of Marienberg, in Saxony, that the miners took flight in alarm, and ascended by the shafts to the surface, where, nevertheless, they found that no shocks or trembling had been felt.

40. On the other hand, the superficial strata are sometimes affected by undulations, from which inferior strata are exempt, as is proved by what took place at Fahlun and Persberg, a mining district of Sweden, in November, 1823, during a violent shock of an earthquake, which spread terror among the inhabitants, while the miners employed in the deep workings experienced no disturbance whatever.

41. The undulations of earthquakes proceed so often in directions parallel to mountain chains, that it might be conjectured that they are directed by some influence exerted by the walls of

the fissures of the strata, between which the matter forming the chain was originally forced up. Many exceptions, however, to this are presented by earthquakes which have been propagated in directions transverse to those of the mountain chains. Thus, in South America they have crossed the littoral chain of Venezuela and the Sierra Parime. In Asia they have been propagated in January, 1832, from Lahore and the foot of the Himalaya, across the chain of the Hindoo Coosh as far as Badakschan on the Upper Oxus, and even to Bokhara.

42. We shall conclude this brief notice of these terrible terrestrial perturbations by the general reflections upon them made by Humboldt, who himself witnessed so many, and who has more than any other observer of nature studied and investigated them.

"In conclusion," says he, "I would advert to the cause of the deep and peculiar impression produced on the mind by the first earthquake we experience, even if it is unaccompanied by subterranean noise. I do not think that this impression is produced by the recollection at the moment of the dreadful images of destruction which historic relations of past catastrophes have presented to our imaginations: it is rather occasioned by the circumstance that our innate confidence in the immobility of the ground beneath us is at once shaken. From our earliest childhood we are accustomed to contrast the mobility of water with the immobility of the earth: all the evidences of our senses have confirmed this belief; and when suddenly the ground itself shakes beneath us, a natural force of which we have had no previous experience presents itself as a strange and mysterious agency. A single instant annihilates the illusion of our whole previous life; we feel the imagined repose of nature vanish, and that we are ourselves transported into the realm of unknown destructive forces. Every sound affects us —our attention is strained to catch even the faintest movement of the air—we no longer trust the ground beneath our feet. Even in animals similar inquietude and distress are produced; dogs and swine are particularly affected, and the crocodiles of the Orinoco, which at all other times are as dumb as our little lizards, leave the agitated bed of the river, and run with loud cries into the forest.

"To man the earthquake conveys a sense of danger of which he knows not the extent or the limit. The eruption of the volcano, the flowing stream of lava threatening his habitation can be fled from; but in the earthquake, turn where he will, danger and destruction are around him and beneath his feet. Though such emotions are deeply seated, they are not of long duration. The inhabitants of countries where long series of weak shocks succeed each other, lose almost every trace of fear. On the coasts of Peru,

where rain scarcely ever falls, and where hail, lightning, and thunder are unknown, these atmospheric explosions are replaced by the subterranean thunder which accompanies the trembling of the earth. From long habit and a prevalent opinion that dangerous shocks are only to be apprehended two or three times in a century, slight oscillations of the ground scarcely excite so much attention in Lima as a hail-storm does in the temperate zone."

43. Although we are in the habit of congratulating ourselves, in this country, for our exemption from the terrible visitations of convulsions of the ground, it is certain that beneath the floor upon which our dwellings are established, there exists a seat of disturbance of a certain force and constancy. This is abundantly proved by the fact, that not less than 256 or 257 slight earthquake-shocks have been recorded, of which 139 took place in Scotland. Yorkshire, Derbyshire, Wales, and the south coast of England, have been the principal theatres of the remainder.

44. In the cases of convulsions which have been noticed in the preceding chapter, the effects of the phenomena have been generally limited to derangement more or less violent of the surface. When the internal forces acting outwards are exercised with greater energy, or when the external strata of the earth's crust exercise less resistance, disruptions take place, and through the openings thus produced the internal matter is ejected. The physical character of the matter thus thrown out, and the state in which it is found at the moment of its ejection, depend in a great degree upon the depth of the strata from which it has proceeded.

Of all the substances thus thrown out through the external crust from the interior of the earth, the most frequent is water. That liquid appears to be deposited in terrestrial strata, having depths more or less considerable, and it necessarily acquires the temperature of the strata in which it is thus confined. In ordinary springs rising from inconsiderable depths within the limits of the superficial strata, the temperature in warm seasons is generally lower considerably than that of the air at the surface, and hence arises the coolness of common spring-water. But when water rises from depths much more considerable, lying below the stratum of invariable temperature,* it is found to have a higher temperature than the air.

45. It was first observed by Arago, that water rising in Artesian wells had a temperature greater and greater as the depth of the well augmented. This observation involved a physical principle of high importance, supplying, as it did, a thermal index to the depth of hot springs.

* See Tract on Terrestrial Heat.

46. It has been shown in our tract on Terrestrial Heat, that in descending below the stratum of invariable temperature, the temperature of the strata increases at the rate of about 1° for every 50 feet. The stratum of invariable temperature, at the mean latitudes, being at a depth of less than 100 feet, and its temperature being nearly the same as the mean temperature at the surface; we may state in round numbers, that if the temperature at the surface be taken to be 50°, the temperature at the depth of one mile will be 150°, at the depth of two miles will be 250°, and at the depth of three miles will be 350°. Now, water at the temperature of 250° produces steam bearing a pressure of 30 lbs. per square inch, being about half that of the steam generated in a common locomotive, while water at 350° produces steam having a pressure of 130 lbs. per square inch, being more than twice the pressure in a locomotive.

47. The natural hot springs which exist in various parts of the globe must issue from strata whose depth corresponds to their temperature, rising through fissures or perforations in the superior strata, produced by disruptions effected by the pressure from within prevailing over the tenacity of the materials composing such strata. If the temperature of the water issuing from such springs could be taken to be that which it had in the reservoir from which it has risen, such temperature would supply at least an approximate index of the depth of such reservoir. But it must be considered, that in rising to the surface it passes through a succession of strata of constantly decreasing temperature, composed of materials of various conducting powers and capacities for heat, and that in its ascent it must part with more or less of its heat, and therefore that its temperature on issuing from the spring at the surface must be less than that of the subterranean reservoir from which it has risen. How much must, in each case, be allowed for this loss of temperature is a problem of considerable difficulty, and one which at best, with our present data, admits of no more than a rough approximative solution.

48. Observations made very extensively upon thermal springs, prove them to be completely independent of the strata from and under which they rise. Neither do they prevail exclusively in volcanic regions. Indeed, Humboldt affirms that the hottest permanent springs hitherto discovered are some found by himself, at a great distance from any volcano, as for example, the "Aguas Calientes de las Trincheras," between Puerto Cabello and New Valencia, in Venezuela, South America, the temperature of which was 194½°, and which issued through a stratum of granite; and the "Aguas Comangillas," near Guanaxuato, in Mexico, of which the temperature was 205½°, being only 6½° below the boiling point.

According to what has been explained of the law of temperature in relation to depth, the reservoirs from which these springs rise must be at a depth of nearly two miles.

It is remarked that springs of such moderate temperatures as from 120° to 160° are very constant, not only in their thermal state, but also in their chemical composition, while the hotter springs are subject to considerable variation. Thus, the thermal springs within these limits which have been known and observed in Europe, have never undergone the slightest change, either in their temperature or in their chemical analysis, since exact physical observations have been made upon them, which comprises at present an interval of about sixty years. While the hotter springs contain in solution the smallest proportions of mineral matter, they are found to be subject to a variation of temperature not inconsiderable. Thus, the springs of Las Trincheras above-mentioned, which, when observed by Humboldt in 1800, had a temperature of 194½°, were found by Boussingault, in 1823, to have a temperature of 206½°, having thus increased in temperature 12° in 23 years.

49. Nothing is more remarkable and curious respecting springs, whatever be their temperature, than the secular permanency which attends so many of them. The fountains of Greece still flow in the same places as they did when described by the historians, and sung by the poets, of the classic age. The river Erasinos, which rose in lake Stymphalus, after flowing a certain distance disappeared in the earth, but sprung up again out of the declivity of the mountain Chaon, two hours' journey south of Argos. This spring, which is mentioned by Herodotus, still issues from the same point in the slope of the mountain. In the centre of the temple of Apollo, at Delphi, was a small opening in the ground from which, from time to time, an intoxicating vapour was said to proceed, and which was supposed to proceed from the adjacent well of Cassotis. Over this chasm the priestess Pythia took her seat whenever the oracle was to be consulted, and the words she uttered after inhaling the mephitic vapour were believed to be the revelations of the god.

Of this chasm no trace remains, but the well of Cassotis still exists, and is known as that of St. Nicholas. Its waters still pass under the site of the temple of Apollo.

Of the other classic fountains which still flow may be mentioned that of Castalia at the foot of Mount Parnassus, Piréné at Corinth, the thermal springs of Ædepsus on the coast of Eubœa near Chalcis. It is remarkable that in a tract of country so peculiarly subject to frequent and violent earthquakes, the strata in the main continue to preserve their relative position, so that even those narrow holes and fissures, through which those subterranean waters

force themselves up, have remained unchanged during the long interval of 2000 years.

As further examples of this permanency, Humboldt adduces the example of a natural jet d'eau at Lillers, near Calais, which was bored in 1126, and now, after a lapse of seven centuries, still supplies the same quantity of water, which issues with the same force.

50. If the reservoir from which water rises be at such a depth that its temperature greatly exceeds the boiling point, the water will be converted into vapour the moment it escapes from the place of its confinement, just as was the case with the water shut up in the generators of the steam apparatus projected by Perkins. In that case, the steam will issue from the crevice of the earth exactly as it would from the safety-valve of a high-pressure steam-engine.

51. The vapour of water is not however by any means the only elastic fluid which forces its way to the surface from the interior of the globe. Various gases are also ejected in enormous quantities. The gas called carburetted hydrogen, which, evolved by artificial processes, is now so universally used for the purposes of illumination, issues in vast quantities from the interior of the earth through fissures of greater or less magnitude, and thus presented by Nature herself, has actually been used for illumination in China for more than ten centuries back. The artesian FIRE-WELLS of China, at Ho-tsing are well-known. The gas has from very ancient times been collected in tubes of bamboo, and being thus rendered portable, has been used for illumination in the city of Khiung-tscheu.*

52. But of all the gaseous ejections from the interior, the most frequent and abundant is carbonic acid. It is certain that at earlier epochs in the history of our globe, thousands of centuries before the appearance of man and of the other tribes of animals that now inhabit it, when the fissures and crevices supplying free communication between the surface and the interior were far more numerous and capacious than they are at present, and when the temperature of the solid crust was much higher, this gas, mixed with hot steam, issued from the interior in quantities infinitely greater than at present, so as to give totally different qualities to the atmosphere. These qualities, owing to the large proportion of carbonic acid, and the great quantity of aqueous vapour always suspended in the air, were eminently favourable to the production of a vegetation exuberant to a degree of which there is now no existing parallel. Hence arose those vast forests and other large collections of vegetable matter, which, being fossilised in succeeding

* Humboldt, "Central Asia," tom ii. 519—530.

revolutions of the globe, have supplied those inexhaustible stores of mineral fuel which have, through the application of science, become mechanical agents of infinite power, as well as sources of artificial light and heat.

53. These prodigious volumes of carbonic acid also supplied other purposes in the terrestrial economy at that early period. Entering into combination with lime, which also prevailed in abundance, lime-stone rocks of every kind, including those beautiful marbles which have become so important a material in the industrial and ornamental arts, were produced; for these rocks, as is well known, are nothing but carbonates of lime, the carbonic acid constituting nearly half of their entire mass.

54. The transition from the ejection of gases and liquids to that of molten rocks exhibited in the effects of volcanoes, is marked by the intermediate phenomena of the ejection of hot mud. According to Humboldt, although SALSES or mud volcanoes in their normal state present little to arrest attention, their origin is characterised by the imposing phenomena of earthquakes, subterranean thunder, the upswelling of vast tracts of country, and the ejection of lofty jets of flame. A recent and well-observed example of such a phenomenon is presented in the case of the mud volcano of Jokmali, on the peninsula of Apscheron, east of Baku on the shores of the Caspian sea. This peninsula has always been the theatre of singular subterranean phenomena, and flames have so frequently, in past times, issued from the ground upon it, that it has been regarded with veneration by the oriental fire-worshippers. On this peninsula on the 27th November, 1827, flames blazed up from the ground to so great a height that they were seen at the distance of 24 miles, in which state they continued for three hours, after which they decreased to the height of three feet. They issued from a crater which was formed by their ejection, and continued to burn in that way for 20 hours. This ended in the ejection of enormous fragments of rock, and quantities of hot mud.

55. Of mud volcanoes of more remote origin we have examples in the case of the Monte Zibio, near Sassuolo in the Duchy of Modena, and the salse near Girgenti, in Sicily. Fragments of rocks like those ejected by Jokmali may be seen around the former. The salse has continued in the secondary state of activity for fifteen hundred years, descriptions of it at that early epoch having come down to us. It consists of several cone-shaped mounds, varying in height from eight to thirty feet, and subject to constant change, not only in height but in shape. Small craters are formed at the summit of the cones, which contained more or less water, and from which gas from time to time is disengaged.

The mud which is ejected from these volcanoes is cold. In a similar mud volcano mentioned by Humboldt, at Damak, in the province of Samarang, in the island of Java, the mud ejected has a high temperature.

The gaseous eruptions from these salses are usually attended by noise, and consist of different sorts of gas, sometimes hydrogen, sometimes carbonic acid, and occasionally nitrogen. The hydrogen is often mixed with naphtha.

56. After the first imposing phenomena such as those above described in the case of Jokmali have ceased, the mud volcanoes in general seem to be the result of a feeble activity of the interior forces of the globe obstructed in their effects by some impediments in the fissures or openings by which communication with the surface is obtained. The coldness of the mud seems to prove that the seat of the force is not at any great depth.

57. From the examples of subterranean activity presented by superficial convulsions, earthquakes, thermal springs, and jets of gas and steam, we pass to the formation of volcanoes properly so called. The internal forces, acting with unequal effect on different parts of the solid crust of the earth, surmount its resistance at points where it has least tenacity, and upheaving the incumbent strata, raise them into dome-shaped masses, like those of the Puy de Dome and Chimborazo, without, however, producing actual fracture. Sometimes the mass thus upheaved gives way at the summit of the dome, which separates so as to leave a circular cavity of a certain depth surrounded by a nearly perpendicular wall, having on the exterior a gradual slope, which formed the declivity of the dome before the disruption.

58. The roundish cavity thus formed is called a "crater of elevation."

59. If the energy of the subterranean forces be sufficiently intense, the floor of this crater will be disrupted, holes and fissures will be formed in it, communicating with the liquid fire which fills the solid shell of the earth, steam and acid gases will be ejected in vast quantities, followed by ignited scoriæ, and red hot stones, and fragments of rock, after which will follow torrents of that incandescent earthy matter in a state of pasty fusion, which has been called LAVA; in a word, an active VOLCANO will be formed.

60. Now there are here several distinct stages, at any one of which the phenomena may be brought to a close, according to the relation between the energy of the upheaving force and the local tenacity of the earth's solid crust. If the upheaving force do not much exceed that tenacity it may spend its entire energy in producing swelling of the surface of the ground more or less pro-

nounced. If the excess be greater still, a dome-shaped hill or mountain will be produced. A greater excess again will cause the disruption of this dome, and its conversion into a crater of elevation. Finally, if the internal force be sufficient to break a way through the entire mass of solid strata which forms the shell of the earth, the fiery fluid central matter, rising through the opening thus made for it, will issue from the holes, crevices, and fissures in the floor of the crater, and overflowing or breaking a way through the surrounding wall, rush in a torrent of fire down the slopes of the dome-shaped hill thus formed.

61. The volcano thus formed is never uniformly active. The eruptions are only occasional. When an internal wave or tide of the fiery central ocean passes the base of the opening, a pressure is produced by which the molten matter is forced up and ejected in the form of lava. In its ordinary state, however, when no eruption takes place, volumes of smoke more or less dense usually rise from the fissures, and upon looking down into them, the luminous incandescence of their walls and of the matter they include is visible. The light of this illuminating the smoke and ashes, which rise over the crater, often give to them a lurid light which appears like, and is sometimes mistaken for flame.

62. The intervals of activity and repose of volcanoes are often of very long duration. Thus in the case of Vesuvius, the eruptions were renewed with unabated force after an interruption of several centuries. In the time of Nero, Etna was considered as approaching to entire extinction, and according to Ælian, the summit of the mountain at a later period was gradually sinking, so that it could no longer be seen as a landmark by vessels at sea from the same distances.

63. Humboldt affirms that it may be considered as a pretty well established law of volcanoes that those which have least elevation are characterised by the most unceasing activity. He proves this law by many examples, and explains it by the supposition that a less internal force is sufficient to raise the molten masses to low than to high summits. He gives the following series of elevations of the craters of remarkable volcanoes:—

	Feet.
Stromboli	2318
Guacamayo	2500
Vesuvius	3876
Etna	10,870
Peak of Teneriffe	12,175
Cotopaxi	19,070

64. Now of these, Stromboli has been in a state of activity from the Homeric age to the present, so unceasing that it has served

and still serves all the purposes of a stupendous light-house to ships navigating that part of the Mediterranean. The entire island situate off the north coast of Sicily is of volcanic formation.

65. The activity of Guacamayo, situate in the province of Quiros, at about 88 miles from Chillo, near Quito, is so continuous that detonations are heard daily from it, even at the distance of Chillo. On the other hand, the eruptions of Vesuvius are comparatively rare, and those of Etna still more so, while those of the lofty volcanic peaks of the Andes are separated by intervals of little less than a century.

66. As a further evidence of the prevalence of this volcanic law may be mentioned the cases in which volcanoes do not rise, like Etna and Vesuvius, from the midst of extensive plains, but have their bases established on table-lands of great elevation, in which cases it is observed, that even in the most terrible eruptions no lava properly so called is ejected, the matter thrown up being merely ignited scoriæ. Yet the violence of the subterranean commotion is rendered manifest by the terrible detonations which are heard at distances of four hundred miles. Examples of this are presented in the volcano of Popayan, South America, the base of which is 6000 feet above the level of the sea, that of Pasto upon the table-land of the Andes at an elevation of 8500 feet, and those of the Andes near Quito.

67. Wherever exceptions to this volcanic law have been presented, Humboldt considers them as only apparent, and that they may be explained by the casual obstruction of the fissures of communication between the seat of the volcanic force and the surface.

68. The volcanic eruptions do not necessarily proceed from the crater. Indeed, in some volcanoes, eruptions from the crater are much less frequent than those which proceed from other parts of the mountain; as, for example, from the sides where the solid walls of the internal fissure often present less resistance. Lateral fissures and openings are in such cases produced, over which "cones of eruption," as they are called, are formed. In this case, a series, or row of cones, are formed at certain distances along the line of fissure, from each of which the eruption takes place, all the intermediate part of the fissure being immediately closed up.

69. The internal forces also often break out at numerous points, distributed over a large space, forming a number of smaller cones which are described as having the form of bells or beehives. The cones produced by the eruption of Vesuvius in October, 1822, offer an example of these, as do also the Hornitos de Jorullo, observed by Humboldt, and delineated by him in his

"Vues des Cordillères," pl. XLIII., p. 239. Other examples are presented by the small cones of the volcano of Awatscha, and of the field of lava in Kamtschatka, described by Erman.

70. Around each mouth from which the fiery matter is projected, a cone of cinders and ashes is formed by the return of the matter which has been projected upwards. These cones vary greatly in height and magnitude, and appear to have no relation to the general elevation of the mountain, the smaller class of volcanoes often producing the highest cones. One of the most remarkable of these cones is that of the Volcano of Cotopaxi, in the eastern Cordillera of the Andes, about 34 miles S.S.E. of Quito. The general form of this remarkable mountain is that of an immense cone, shaped with an accuracy almost geometrical. The summit is about 19000 feet above the level of the sea, and nearly 10000 above the adjacent table-land. The snow line is at 4400 feet below the summit. The cone, therefore, above this line is coated with perpetual snow, except at the times of eruptions, in which the solid sides of the cone becoming incandescent, the snow suddenly melts, and descending in torrents down the flanks of the mountain, leaves the conical summit uncovered. "Of all the volcanoes which I have seen," says Humboldt, "in either hemisphere, the cone-formed Cotopaxi is at once the most regular and the most picturesque. Before each great eruption, the sudden fusion of the snow, which habitually invests its vast cone, announces the coming catastrophe. Even before the appearance of smoke issuing from its lofty crater, the sides of the cone acquire a glowing temperature, and the mass of the mountain assumes an aspect of most awful and portentous blackness."

71. It is difficult to imagine any spectacle more awfully grand than the view of a crater in activity presented to an observer stationed at the summit of the surrounding wall. The space beneath him appears like the surface of agitated half-molten matter contained in a colossal cauldron. The surface swells and intumesces; from the cracks and fissures vapours issue; small chasms here and there alternately open and close, showing within them red hot molten matter; burning fragments are from time to time thrown up, and fall back upon the sides of the mounds surrounding the mouths from which they have been vomited; each small eruption of this kind is regularly preceded and announced by small earthquake shocks, which sensibly shake the ground beneath the feet of the observer; occasionally lava issues in a fiery torrent from these fissures and mouths, but not in sufficient quantity to break through the walls of the crater, but sometimes the flow of this red hot pasty matter is so abundant

that it breaks the wall, and rushes down the side of the mountain.

72. It might be inferred from the occurrence of such tremendous phenomena, that the form and condition of volcanic craters would be subject to constant and considerable change. Their variation is, nevertheless, much less than might naturally be expected. Thus, for example, the ramparts of the crater of Vesuvius were accurately measured by Saussure in 1773, and again by Humboldt and Lord Minto in 1822-3. In that interval of 50 years no considerable variation took place.

73. The case of Cotopaxi producing torrents of water mixed with scoriæ and enormous blocks of ice precipitated down the slopes of the mountain by the sudden fusion of the snow which crowns its summit, is not singular. The same phenomena attend all the volcanoes whose cones rise above the line of perpetual snow, of which the chain of the Andes presents many examples. Independently of these occasional inundations of the external surface, these volcanoes exert a constant action even during their apparent repose, by the slower fusion of the snow in immediate contact with them, and the infiltration of the water through the crevices and fissures of the rocks of which they are formed. Subterranean reservoirs of water are thus formed at and below their bases, with which the streams and rivulets of the surface communicate. It has been ascertained that in these dark reservoirs fish multiply more largely than in the open waters, and that when the caverns containing such waters are suddenly opened, as they sometimes are, by the earthquakes which always precede violent eruptions, water, fish, and tufaceous mud are thrown out in one confused mass. Humboldt says, that when on the night of the 19th June, 1698, the summit of the Carguairazo, at the height of nearly 20000 feet above the level of the sea, suddenly fell in, leaving two stupendous peaks of rock as the sole vestiges of the rampart of the crater, masses of tufa, in a liquid state, and of clayey mud, containing immense numbers of dead fish, were spread over a tract of about fifty square miles in extent, rendering the whole space barren.

In some cases, the quantities of this dead fish which have been ejected have produced putrid fevers, fatal to a large part of the population.

74. The fiery appearance which is so often observed over the volcanic craters in great eruptions is not flame, as it is commonly supposed to be. It is due principally, if not altogether, to the reflection of the lurid light which issues from the crater, by which the clouds, vapour, ashes, and other ejected matter, forming the column over it, are illuminated, but in part, also, from scoriæ and

dust ejected in a state of incandescence. There is, strictly speaking, no combustion in or over the crater, and therefore the term burning mountain is physically incorrect.

75. The production of volcanoes, or of volcanic craters, which remain passive, as above explained, is by no means confined to those parts of the solid crust of the earth which lie above the waters of the ocean. The bottoms of seas, and even of lakes, are subject to such convulsions still more frequently than the land. When the bottom of the sea is thus up-heaved, islands are produced, the form, character, and magnitude of which depend on that of the up-heaved mass. The form of Palma, one of the Canaries, and the peaks which it throws up to the height of 7000 feet, and that of Nisyrus in the Ægean, present examples of this. The volcanic origin of the latter was known to the ancients, which gave rise to the fable that Neptune, when pursuing Polybotes, one of the giants that fought against the gods, followed him across the sea as far as this land of Cos, where having torn off a part of the island, he hurled it upon him, and buried him under it. This fragment of Cos was called Nisyrus.

When the dome up-heaved from the bottom of the sea breaks at the summit, so as to form a crater of elevation, a part of the annular rampart is sometimes destroyed, so that the sea enters, and an enclosed bay is formed, where innumerable tribes of coral animals build their cellular dwellings.

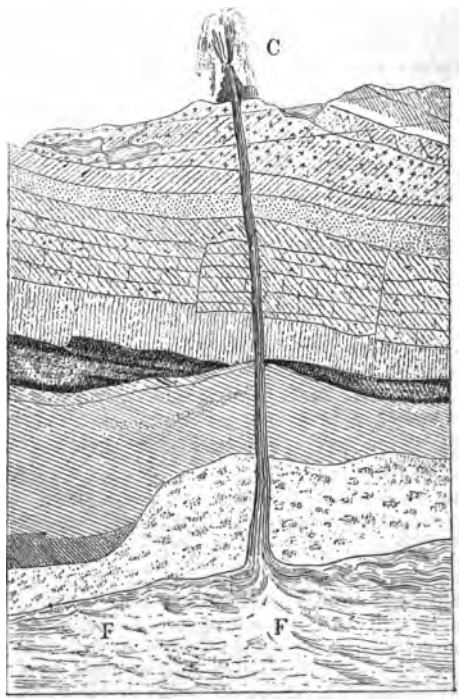
It happens also frequently that the craters of elevation on land become filled with water, so as to form lakes surrounded by a rampart.

76. Various theories have been proposed to explain the phenomena of volcanoes, and to solve the questions, What is it that burns? What excites such prodigious degrees and quantities of heat? heat sufficient to fuse not only the metals, but the most refractory earths, imparting to masses of fused earth a heat which many years are required to dissipate. We have throughout these pages assumed, that the origin of all these phenomena is the fluid incandescent matter contained within the solid crust of the earth, such being, after much discussion, the explanation now generally accepted by geologists. Among the hypotheses which have been proposed, and which received and merited much consideration, though now put aside, was the chemical theory of Sir Humphry Davy, in which the evolution of heat and light in the depths of the volcanic craters, was ascribed to the chemical action of the most oxydable metals, such as potassium, sodium, calcium, &c. It is a fact, familiar to all that have studied the elements of chemistry, that a piece of potassium immersed in water will instantly become decomposed, combining with its

oxygen and liberating the hydrogen. If the existence of the metals in their simple state in the lower strata of the earth be admitted, any accession of water to them would immediately produce this sort of combustion.

Our limits, and the object of this tract, preclude us from entering upon this question here beyond this mere indication of the ingenious hypothesis of the illustrious chemist; and as the theory proposed has been generally abandoned, such a discussion is the less necessary.

To illustrate the generally received theory, we have here subjoined an hypothetical section of the crust of the earth, showing the progress upwards of the igneous fluid from the internal liquid fire, FF, to the mouth of the crater at C.



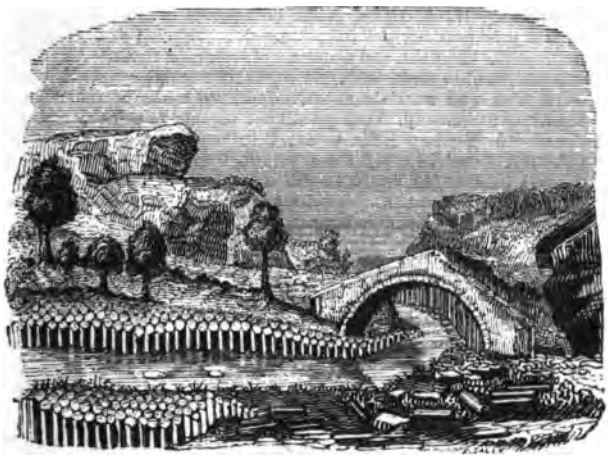


Fig. 31.—BASALTIC CAUSEWAY OF THE RIVER VOLANT. (DEP. ARDECHE, FRANCE.)

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER I.

1. The earth, a subject of long-continued observation and investigation.—2. Mathematical geography.—3. Physical geography.—4. Phenomena of the oceans and seas included in it.—5. Hydrology, meteorology, and climatology.—6. Political geography.—7. General subject of geography.—8. Geology.—9. Original fluidity of the earth inferred from its spheroidal form.—10. This form ascertained by observation and measurement.—11. The solid crust was formed while the earth was in a state of rotation.—12. Increase of temperature from surface downwards.—13. Within the crust the earth still in a state of fusion.—14. Subject of geology.—15. How the structure of the crust to a great depth is rendered manifest.—16. Section of the crust where no disturbance has taken place—strata occur in a fixed order.—17. Rocks in their geological sense.—18. Their classification in five principal divisions.—19. Lowest bed, being the foundation of the crust, consists of igneous rocks produced by the superficial cooling of the molten materials of the globe.—20. Materials of which the igneous rocks are formed.—21. Constituents of granite, feldspar, mica, quartz.—22. These components of igneous rocks agglomerated mechanically.—23. But the components themselves are chemical compounds.—24. Varieties of granite—porphyry.—25. Gneiss.—26. Secondary rocks.—27. Transition or metamorphic rocks.—28. Stratification.—29. Produced by aqueous

deposition.—30. Stratified rocks of aqueous origin.—31. Circumstances corroborating this inference.—32. Stratified and unstratified rocks.—33. Condition and materials of transition rocks.—34. Animal remains found in them.—35. No vegetable remains—probable reason.—36. Fish and annelidans.—37. Stratified rocks in general.—38. Secondary rocks.—39. Vast quantity of organic remains deposited in them.—40. Tertiary rocks. — 41. Diluvium, alluvium, and surface soil.—42. Subdivision of these principal groups of strata. — 43. General inference as to the condition and ages of stratified rocks.—44. They constitute a chronological scale. — 45. Complexity and defects of geological nomenclature.

1. It cannot be matter of surprise that of all the great bodies of the universe the earth, which has been assigned by the Creator as the habitation of the human race, has received the largest share of attention on the part of those who have devoted their faculties to the observation and investigation of nature. Regarded in different points of view it has formed the exclusive subject of several branches of science.

2. Taken in its entire mass, and considered in relation to the other bodies of the solar system, it constitutes the subject of MATHEMATICAL GEOGRAPHY, which includes the solution of such problems as the determination of the magnitude of the earth—its exact form—its relation to the other bodies of the solar system—its annual motion round the sun which produces the apparent movement of that luminary through the signs of the Zodiac—its diurnal rotation which produces those apparent motions of the firmament which cause the vicissitudes of day and night—the peculiar position of its axis which produces the succession of seasons—the division of the globe into zones and climates, and the system of imaginary circles of latitude and longitude which supply the means of expressing the position of all places on the globe, relatively to each other, and to the equator and poles.

3. The earth, viewed in regard to the various physical states of its surface, constitutes the subject of PHYSICAL GEOGRAPHY, which includes a description of the distribution of land and water—the extent and configuration of continents and islands—the elevation and prevailing direction of mountain chains—the form, extent, and direction of plains and valleys—the general altitude of the surface of the land above the common level of the sea—the effects of soil and climate, and the local distribution of animal and vegetable productions.

4. This division of geographical science also includes the various phenomena of the ocean and seas, their depth, saltness, and temperature, the prevailing direction and velocity of ocean currents, the extent of the polar ice and circumstances incidental to it.

5. The subdivisions of physical geography are sometimes denominated HYDROLOGY, which includes all that relates to the ocean and seas; METEOROLOGY, which includes the investigation of atmospheric phenomena; and CLIMATOLOGY, which involves the consideration of the mean temperature of different countries, the altitude of the line above which there is perpetual snow, the prevailing winds, the barometric pressure, the annual quantity of rain, and so on.

6. The earth, considered as the abode of mankind, distributed into different nations and placed under different forms of government, constitutes the subject of POLITICAL GEOGRAPHY, which therefore includes the consideration of the moral and social condition of different peoples, their language, religion, forms of government, and civilisation, and the population, resources and local relations of different countries.

7. It appears, therefore, that these several divisions of geographical science are limited to the appearances and phenomena developed upon the surface of the earth, in the waters which partially cover it, and in the atmosphere by which it is surrounded.

8. Another, and not less important department of science concerning the earth, relates to the condition and structure of those parts of the globe which lie between its surface and its centre, and which constitute the subject of GEOLOGY.

9. In mathematical geography and astronomy, certain physical circumstances attending the interior of the earth have been developed. Thus it is proved that the density of the globe gradually increases from the surface to the centre; and from its peculiar form it is inferred that, at the epoch of its formation, the materials composing it must have been in a fluid state. It has been already shown in our Tract on the "Earth," that the form of the globe is what in geometry is called an *oblate spheroid*, a figure somewhat resembling an orange or a turnip. By reason of this figure, the earth is flattened at the poles and bulged out at the equator. Now it is proved in mathematical physics that if a fluid globe have a motion of rotation on one of its diameters as an axis, the centrifugal force of the matter composing it will cause it to bulge out at the equator and to flatten at the poles, so that all sections of it made by planes passing through the axis are ellipses, and the degree of the elliptic form of these sections will be so much the greater as the velocity of rotation is more rapid; and so closely connected is this degree of ellipticity with the velocity of rotation, that mathematicians are able to assign the exact form of the elliptic section which must correspond to each particular velocity of rotation.

10. Before the exact form of the earth had been determined by

direct observation and measurement, mathematicians had already ascertained by computation what ought to be its form consequent upon its rotation upon its polar axis, and the time in which it is actually known to rotate, and the result of their computations was afterwards found to agree with the utmost possible numerical precision with the actual form which the earth was proved to have by immediate observation and measurement.

11. It is therefore inferred from this that the earth, in its original state, and before it assumed its present condition, was a fluid mass, and that while in this fluid state, it received the diurnal rotation by which it is now affected, and which produces the vicissitudes of day and night. It was, therefore, after having assumed this spheroidal form, that its superficial parts hardened and solidified, and after undergoing a certain succession of changes assumed their present condition.

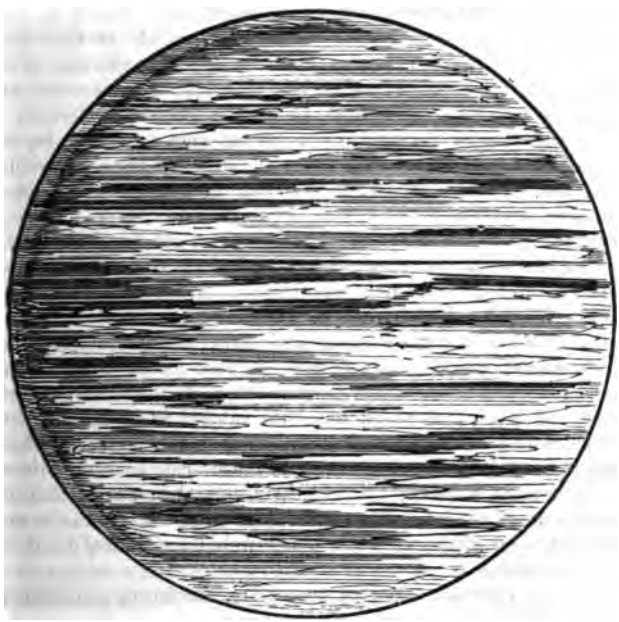
12. It has been also shown in our Tracts on "Terrestrial Heat," and on "Earthquakes and Volcanoes," that when we penetrate into the crust of the earth by mines, boring, or other artificial means, the temperature is found to undergo a gradual and regular augmentation, and this augmentation being continuous, so far as direct observation has been carried, may be assumed by analogy to increase to a still greater depth in the same proportion—a conclusion which also is verified by the phenomenon of hot springs rising from a considerable depth, and by various volcanic effects. Assuming this gradual increase of temperature to go on indefinitely in descending towards the centre, it has been shown that at a certain depth the temperature must be such that even the most refractory constituents of the globe would be reduced by it to a state of fusion.

13. The increase of temperature being at the rate of about a hundred thermometric degrees per mile, it would follow that at the depth of about 40 miles, or about the 100th part of the entire distance from the surface to the centre, we should arrive at a temperature of 4000°, at which it is quite certain that no part of the matter composing the earth could remain solid. It is therefore inferred, without the necessity for extreme numerical precision, that the earth is a spherical shell, the superficial part only being solid—all the central part being in a state of igneous fusion—the thickness of the solid crust being, as just stated, about the 200th part of the entire diameter. A section of it would be such as is represented in fig. 1.

If, therefore, as we have already stated in our Tract on "Earthquakes and Volcanoes," the egg of a fowl be imagined to represent the earth, its shell would be much too thick to represent its solid crust.

It is no rhetorical exaggeration that the globe we live on is a stupendous, but very thin spherical shell, charged with liquid fire; and if such be the case it may naturally be asked how it happens, that so thin a crust supported on a fluid so mobile can maintain that

Fig. 1.



general state of stability which characterises it so strongly, that it is referred to in times ancient and modern as the type of all that is most solid and most durable. An answer to this reasonable question will be collected from all we shall have to explain in the present Tract.*

14. The investigation of the structure and condition of this solid crust of the terrestrial spheroid, extending from the fluid

* According to Mr. Hopkins, the thickness of the crust is subject to much local variation, being very unequal on its inner surface. He considers that it is probably cavernous, and that masses of fluid mineral matter may be distributed through its cavities. According to him the thickness in some parts may be as great as 800 or 1000 miles. See Memoirs on the State of the Interior of the Earth, in the Philosophical Transactions from 1839 to 1842.

nucleus upon which it is supported to the surface, constitutes the subject of geology.

15. Considering that however thin may be the crust of the earth as compared with its diameter, its absolute thickness being at least from 30 to 40 miles, and that this very far exceeds any depth which is accessible to direct observation, it might be imagined that all attempts at an analysis of its structure would be vain and futile. A circumstance nevertheless which at first view would seem to throw difficulties insurmountable in the way of the solution of this problem has, on the contrary, happily facilitated it. This circumstance consists in certain local irregularities in the actual state of the solid crust. What man could not do, the accidental effects of internal forces has done for him. The solid crust has been locally disrupted, so that its section in some cases for many miles of depth has been turned upwards and exposed to direct observation. It will be sufficient here to allude briefly to this as one of the principal means, by which the structure of the terrestrial crust has been ascertained. The point will be more fully developed hereafter.

16. To explain the condition and structure of the terrestrial crust, we will suppose in the first instance a part of the earth's surface to be selected, which throughout a considerable extent is plane and level, and which has been subject to no derangement of structure by internal convulsion, so that the materials which form it, extending from the surface to the internal igneous fluid on which it rests, have remained in their normal and original order and state. If we imagine a vertical section of the crust in such a situation to be made extending indefinitely downwards, it will be found to consist of a series of strata superposed in a certain fixed order, each stratum, taken in succession, consisting generally of the same constituents in the same state.

17. The matter composing these strata is called by geologists ROCKS, a term used in this science in a sense somewhat different from its common popular signification. ROCKS in the geological sense does not necessarily imply masses of stone. It signifies any agglomeration whatever of matter which may be found to enter into the composition of the crust of the earth. In this sense clay and sand come under the name of ROCKS as well as granite and marble.

18. Taking then the term rocks in this extended sense, the successive strata composing the shell of the earth is found to consist of different layers of rock, each layer being characterised by rocks existing in a peculiar state of aggregation.

The strata thus superposed, and extending from the fundamental layer which rests immediately upon the matter in igneous

fusion within the terrestrial shell upwards to the surface, are very numerous.

They have, however, been reduced to the five following classes proceeding upwards.

1° The igneous rocks.

2° The transition or metamorphic rocks.

3° The secondary rocks.

4° The tertiary rocks.

5° The diluvial and alluvial layers of matter upon which the superficial soil is spread.

We shall first briefly notice these five great layers, each of which, however, as will hereafter appear, consists of numerous subordinate courses or strata.

19. The lowest or fundamental layer, called igneous rocks, consists exclusively of agglomerations of mineral masses in a state of crystallisation. This is the condition which matter would necessarily assume, and which it could only acquire by having been gradually cooled and solidified, after being brought to a state of fusion by a great elevation of temperature. Under such circumstances its chemical constituents would group themselves according to their mutual affinities, and would assume the various crystallised forms proper to them. After cooling and solidifying, the materials would present the appearance of an agglomeration of crystals thrown arbitrarily together and without regularity or order. Now this being exactly the appearance presented by the rocks which form the foundation of the crust of the globe, it is inferred that they were originally in a state of igneous fusion, and that by the gradual loss of heat by radiation, they were superficially cooled and solidified. The parts of the primitive rocks which have been brought under the observation of geologists are considered as forming the external parts of this solid layer.

These rocks are from circumstances here explained often denominated PLUTONIC or IGNEOUS ROCKS, or ROCKS OF IGNEOUS ORIGIN.

20. Those primitive layers, which may be regarded as the original materials of which the entire crust of the globe is formed, consist chiefly of that rock familiar to all observers of mountainous countries called GRANITE, the most imperishable of all stones, and therefore the most precious for the purposes of construction. This granite is mixed in the fundamental layer in smaller proportions with the minerals called AMPHIBOLE, PYROXENE, and PERIDOTE.

21. Granite is an agglomeration of the crystals of three minerals, called FELDSPAR, MICA, and QUARTZ. Feldspar is the soft grey part of the granite, which is easily scratched. The

oxides of iron and manganese are occasionally mixed with this constituent of granite, and though present in extremely minute quantity, produce nevertheless a very striking appearance, rendering the rock white, cream-coloured, or red, according to their varying proportions.

MICA is the shining glossy particles of the stone, which reflect light like bits of glass or metal. The name is derived from "MICANS," *glittering*. Mica may be seen in many other stones, as also in sand.

QUARTZ, which appears in granite in the form of white crystals, is the substance known as SILEX or SILICA, or the EARTH OF FLINTS, and is one of the hardest and most abundant of mineral substances, entering largely into the composition of many other mineral masses. It is from this constituent, chiefly, that granite receives its hardness.

Silica is familiarly known as ROCK CRYSTAL.

22. It must be remembered that the several materials of which the igneous rocks are thus composed, are not combined together chemically. They are not combined for example in the same manner as are sulphur and oxygen, when these constituents produce vitriol. They are on the contrary merely agglomerated and brought into mechanical juxtaposition, forming a solid mass by the mere cohesion of crystal to crystal, so that by the action of mechanical force it would be possible to resolve the rock into its component parts.

23. Each of these constituents is, however, itself a compound. Thus feldspar is a compound of the silicates of several chemical substances, such as alumina, lime, and potash, or soda—that is, it is a combination of these severally with silicic acid.

Mica is composed of like silicates, with the addition of silicate of iron.

Quartz is in fact silicic acid itself. It will appear, then, from this statement, how important a part silex, or earth of flints, plays in the formation of the globe.

24. If the constituents of the igneous rocks were combined, one with another, chemically, instead of being mechanically juxta-posed, they would, according to a general law of nature, always be found to prevail in the same rocks in one invariable numerical proportion; but being, as explained above, merely agglomerated by cohesion, without any chemical union, they may exist in any proportion whatever, and hence have arisen a corresponding variety of granites. In some specimens the quartz and mica are altogether absent, and then the granite, consisting of feldspar only, in the pasty and crystallised state, takes the name of PORPHYRY.

In other specimens, the proportion of feldspar being large, and that of mica and quartz small, the rock is called PORPHYROUS GRANITE.

25. In general, the little laminæ of mica are distributed irregularly through the granite, their faces being turned in all conceivable directions. In certain specimens, however, they are observed to be placed parallel to each other, so as to give the rock a lamellated, slaty, or schistous texture. The granite, in such cases, takes the name of GNEISS, from the Danish "*gnister.*"

26. Having thus briefly described the composition and condition of the fundamental layer of matter, upon which the solid shell of the earth is based, and indicated the circumstances and characters which are evidence of its igneous origin, we shall now proceed to explain the condition and character of the superincumbent strata, which, as will presently appear, have had an origin of a very different kind, and dates of incomparably more recent formation.

27. The strata which rest immediately upon the igneous rocks have been denominated TRANSITION or METAMORPHIC, inasmuch as they partake partly of the character of the igneous rocks, and partly of that of the rocks incumbent upon them. They partake, in certain instances, of so much of the former and so little of the latter, that in the earlier epochs of geological research, they were classed with the igneous rocks, from which, nevertheless, they are distinguished by sufficiently evident marks of incipient stratification.

28. It has been explained that the materials composing the igneous rocks are confusedly and irregularly agglomerated without the least appearance of even an approach to any regularity of structure, and it has been shown, that this is at once the consequence and evidence of their igneous origin. Such, however, is not the character of the superincumbent rocks. The materials of which these are severally composed are found to be distributed, one over another, in regular layers, bounded by parallel and horizontal surfaces, resembling the courses of masonry. Now such a distribution never could have resulted if these, like the primary rocks, had, previously to their formation, been in a state of fusion.

29. Such an arrangement, on the other hand, is precisely that which would ensue, if the materials, composing the strata, having been mixed with, and suspended in water, had, after the fluid became tranquil, gradually subsided and settled at the bottom. In such a case, the matter thus subsiding would be deposited in a regular series of layers, one above the other, with level and parallel surfaces. The lowest layer would be composed of the heaviest part of the matter held in suspension by the water, that

being the most prompt to sink. Next would come layers of less ponderous matter, and then another lighter still, and thus layer upon layer would be deposited until the whole of the suspended matter would have subsided.

If from any cause after this subsidence the water retired, the ground forming its bottom would be left bare, and the dry land would, if it were excavated, be found to consist of the succession of strata here described.

Now if the actual layers composing the successive strata, which are superincumbent on the igneous rocks, did really in their origin proceed from such a cause, it might be expected that they would succeed each other in the order here indicated, those most apt to subside holding the lower position, and such accordingly is found to be the case.

30. In accordance with these results of observation on the strata forming the crust of the earth, and with concurrent evidence deduced from other appearances, it has been inferred, with a degree of probability amounting to moral certainty, that the stratification has resulted from such a series of physical causes as those above described. Each stratum consisting of a series of parallel layers is assumed to have been a sedimentary deposit precipitated from water, by which the surface of the solid part of the globe has been at former epochs covered, and that these waters having become quiescent before retiring, the matter suspended in them was deposited in layers having more or less regularity, their surfaces being parallel and level, or nearly so.

31. Among the many collateral circumstances which corroborate these conclusions may be mentioned two.

First, the frequent occurrence in the bounding surface of the layers of the form of the ripple of water, as it is observed in the sands of the sea shore after the fall of the tide has laid them bare.

An example of such traces left upon the beds of carboniferous limestone and Portland-stone, in the neighbourhood of Boulogne, is shown in fig. 2.

Fig. 2.

Secondly, by the remains of various aquatic animals and plants, which are often preserved in their natural position, in

which they were tranquilly buried by the matter deposited upon them. Numerous remains of crustacea and mollusca are thus found in perfect preservation in strata situate at great distances from the shores of the sea, figs. 3, 4.

Fig. 3.

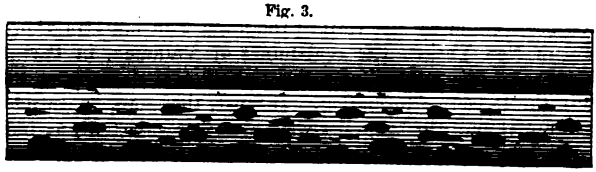
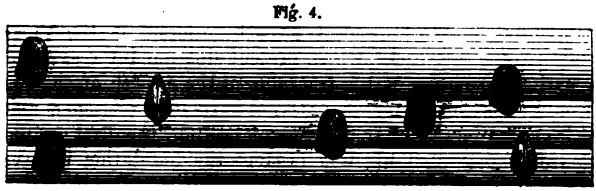


Fig. 4.



These phenomena will be more fully explained hereafter.

32. These circumstances establish a marked distinction between the igneous and the superincumbent rocks. The latter, consisting of matter distributed in regular and horizontal layers are called STRATIFIED ROCKS, while the former consisting of materials agglomerated without any semblance of order are called UNSTRATIFIED ROCKS.

As the unstratified rocks are called PLUTONIC or IGNEOUS ROCKS, the stratified are denominated NEPTUNIAN or SEDIMENTARY ROCKS, and sometimes ROCKS OF AQUEOUS ORIGIN.

33. The transition or metamorphic rocks, which rest upon the igneous rocks, show traces of stratification combined with such partial crystallisation as may be inferred to have arisen from their contact with the highly heated surface of the rocks below them. The principal rocks composing the transition-system, are the gneiss, already described, crystallised limestone, quartz, hornblend, thick layers of the rock called the old-red sandstone, and many varieties of slate and shale.

34. Independent of the existence of distinct stratification in these, they are still more decidedly distinguished from those of igneous origin by the deposits of animal remains found in them, which, though neither numerous nor of a high order of organisation, are nevertheless present in sufficient quantity to put aside in the most conclusive manner all other suppositions, than that of sedimentary formation and aqueous origin.

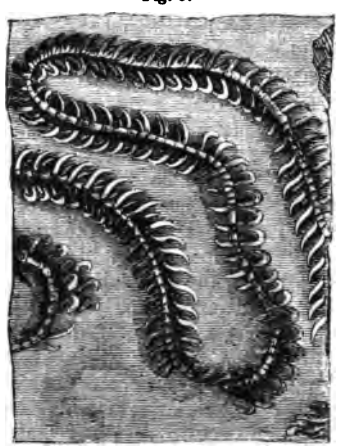
35. It has been assumed by many geologists, that although

animal remains have been found in these transition-rocks, no traces of vegetables were discovered there, from which it was inferred that the existence of animal life upon the globe preceded that of vegetation. M. d'Orbigny has shown, however, that such is not the case. The remains of various marine plants have been found by Mr. Hall in the lower Silurian strata in the State of New York. The coal-mines of Vallongo, in Portugal, are in the same strata; and the richest coal deposits of Spain are in the Devonian formation. It must, therefore, be considered that animal and vegetable life were always co-existent, as indeed is apparent, *à priori*, inasmuch as animals which do not feed on each other must necessarily feed on vegetables.

Organic remains of animals have been found in the superior layers of transition-rocks, which present singular interest as being the earliest examples of life traceable in the growth of the earth. It would seem, that after the external parts of the igneous matter had been hardened by the process of cooling, the first sedimentary layers deposited upon it became the habitation of certain races of organised beings.

36. Among these the researches and observations of Professor Phillips have brought to light various species of small fish, and there have been found, near Llampeter in North Wales, in the same strata, traces of a species which the late Mr. William Macleay, a profound

Fig. 5.



naturalist, pronounced to be a sea-worm of the class of Annelidans, being the first in Cuvier's classification of articulated animals.

The remains of one of these sea-worms, *Nereites Cambrensis*, found at Llampeter, is shown in fig. 5. The body of this creature consisted of about 120 joints.

37. In fine, then, we find that upon the igneous rocks as a foundation the superficial structure of the earth has been erected, consisting of a series of layers or courses of natural masonry, one placed above another—the formation of each of which has been the work of countless ages; that transition-rocks were the first and earliest of these, while those which form the surface of the earth, and are the habitation of the existing organised tribes, were the last; and that the epoch at which these latter tribes, including the human race, were called into existence, remote as it must appear, compared with all measures of time familiar to us, is recent when referred to that system of chronology which is written upon the crust of the globe.

38. Above the transition-rocks, which, as we have stated, were first placed in the class of primitive rocks, succeed a series of layers which have been denominated SECONDARY ROCKS. These consist chiefly of chalk, clay, argillaceous slate, shale, red and brown sandstone, limestone, iron and lead ore, and coal. They abound in organic remains, animal and vegetable, in a high state of preservation, the minutest parts being often perfectly observable.

39. The extent to which the earth was the theatre of organic life, at the epochs of the deposition of these numerous strata, may be conceived when it is stated that, in 1834, a German naturalist and geologist counted no less than 9000 species, the remains of which, at that date, had been found below the superior limits of the stratified rocks, not one of which has ever existed since the earth became the habitation of man.

Among the animal remains which abound in these secondary strata may be mentioned corals, crinoides, mussels, trilobites, fishes, reptiles, insects, marine and fresh-water shells, sponges, and animalcules countless in number.

Of the reptiles, the most remarkable are various species of lizard-shaped animals, constructed on a scale of colossal magnitude, called Saurians, from the Greek word Σαυρος (Sauros), lizard. These have been variously denominated megalosaurus, plesiosaurus, ichthyosaurus, and so on.

40. Upon the secondary rocks repose a series of strata of more recent deposition, called on that account TERTIARY ROCKS. These consist of a thick bed of clay, limestone, sand, pebbles, and white sandstone. They abound in organic remains, which are distinguished from those of the lower and more ancient strata by including a considerable proportion of the still living species. Thus the lowest strata of the tertiary rocks contained 5 per cent.,

and the superior strata 10 per cent. of the species found among the animal tribes which still continue upon the earth.

41. In fine, superposed upon these tertiary are several layers of earthy matter, upon which the actual organised world is placed. These are usually resolved into two beds, the lower of which, denominated DILUVIAL, consists of deposits of gravel and clay, with boulder-stones, rounded in different degrees by attrition, giving indication of having been carried from a distance by the *extraordinary* action of water, from which the general name DRIFT has been given to them.

The superior bed consists of sand, clay, and gravel, upon which the surface soil, which is the theatre of agriculture, rests. This consists of decayed and decomposed vegetable matter, mixed with more or less of the disintegrated matter of the inferior beds. This uppermost layer is produced chiefly by the *ordinary* action of water, and is denominated ALLUVIAL.

42. Such are the five principal groups of rocks, into which geologists have divided the matter which forms the shell of the globe. The transition, secondary, and tertiary groups, have each been subdivided into several layers or strata, each of which is distinguished by the peculiar sorts of mineral matter of which it is composed, and the peculiar species of organic remains which it contains. Geologists, however, are not agreed either as to the limits of the five principal groups, or as to their distribution into subordinate strata. Thus they are not agreed as to where each of the principal groups ends and the next begins. The rocks, which one calls *primitive*, another denominates *transition* or *metamorphic*. Those which one assigns to the upper part of the transition-system, another assigns to the lower part of the secondary system; and in like manner what one assigns as the highest strata of the secondary, another gives as the lowest strata of the tertiary. These discrepancies, however, arise more from the nature of the things than from any deficiency of our knowledge of them. Between one group and another there is no essential distinction, and their classification into primary, secondary, and tertiary, though convenient, is, like many other classifications, to a certain extent arbitrary.

43. From what has been stated, respecting the strata constituting the crust of the earth, the following consequences will follow:—

First. The unstratified and igneous rocks existed prior to the stratified or sedimentary rocks.

Secondly. The stratified or sedimentary rocks were produced in the chronological order in which they are found superposed, the most ancient being the transition-system, and the others being formed in the order of time in which they are superposed,

the oldest being the lowest strata of the secondary, and the most modern the upper strata of the tertiary; the intermediate strata have intermediate dates in the order of their superposition.

Thirdly. The sedimentary strata in their original and natural position were necessarily *level;* their bounding surfaces were horizontal and parallel. Wherever, then, they may be found in any other position, it must be assumed that they have undergone derangement of position by some disturbing cause *since their original deposition.* This derangement may arise either from the strata being heaved upwards by a pressure from below, or by their sinking downwards by their incumbent weight forcing them into some inferior vacuity.

Fourthly. Although the succession of strata constituting the series, from the primitive rocks upwards to the surface, is by no means invariable, and is subject on the contrary to many local variations, still its general character is such as has been described. If the sedimentary strata, proceeding from the lowest upwards, when complete, be expressed by the letters A, B, C, D, &c., it will sometimes happen, from local causes, that the actual series may be A, B, C, E, &c., or A, B, D, E, &c., or A, D, E, &c., but it can never happen that the series shall be D, B, A, C, &c. In a word, one or more strata of the series may be wanting, but their natural order is never inverted.

44. It appears, therefore, that the character and order of the sedimentary strata constitute a chronological scale indicative of the history of their formation. It is true that the value of the unit of this scale is not and cannot be known, inasmuch as the absolute intervals of time, necessary for the deposition of the strata severally, cannot be certainly determined. This, however, does not prevent the geologist from pronouncing with perfect certainty upon the *order* of time of their deposition respectively.

45. Although the series of strata above described have been deposited, subject to so many local disturbing causes, that there is probably no point on the entire surface of the globe, where a section would exhibit them complete, still by a careful and judicious comparison of observations, made in different localities, their normal arrangement and natural order of superposition has been ascertained, and geologists have grouped and classified them under a great variety of denominations. Owing to the absence of any general convention, no single system of nomenclature has been adopted, as has been so happily effected in chemistry, and though in a less degree, also in zoology. The consequence is that geology is overlaid with a complicated, confused, and discordant nomenclature, detrimental to the diffusion and even to the progress and extension of the science. Those

who desire to obtain even the most superficial acquaintance with it, are therefore compelled to familiarise themselves with a mass of most repulsive technicalities, in which the same thing is called by many different names, according to the varying views, tastes, and even personal caprices of the geological investigators who have devoted their labours to the researches in which it finds a place.

Names have been given to strata or groups of strata in some cases from the localities in which they are found at the surface, as for example the Jurassic, the Silurian, the Cambrian, and the Devonian groups. In other cases, names are derived from the prevalent materials constituting them, as the cretaceous, oolitic, and carboniferous groups. Other names have been adopted from the order of the deposits, as for example eocene, miocene, pleiocene, and pleistocene, from Greek words signifying the first dawn, or the earliest, less recent, more recent, and most recent.

Another set of names has been taken from the presence, absence, or dates of the forms of life exhibited by the organic remains found in the strata. Thus the strata, which are destitute of all such remains, are called AZOIC, from a Greek compound implying the absence of life. The term cainozoic is applied to the most recent strata, including organic remains, mesozoic to the middle strata, palæozoic to the ancient strata, protozoic to the first in which life appears, and hypozoic to those strata which lie below the range of all organic remains.

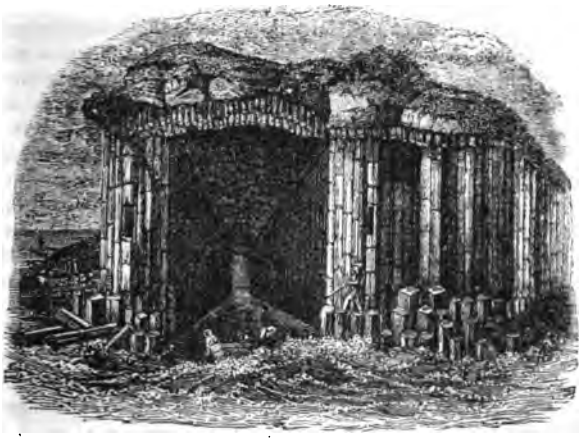


Fig. 37.—CAVE OF FINGAL, STAFFA.

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER II.

46. General section of the terrestrial crust tabulated.—47. Approximate thickness of strata.—48. Probable time necessary for their deposition.—49. Recapitulation of the physical history of the globe.—50. Deposition of organic forms.—51. Alternate elevation and depression of the crust.—52. The strata are botanical and zoological museums of past creations.—53. The gradual increase of forms of life.—54. Creative power has always operated on the same general plan.—55. But has varied from period to period in details.—56. Animals created gradually; the more perfect being the more recent.—57. Tabular view of the progress of the animalisation of the earth.—58. Great increase of vertebrates in the tertiary period—No human fossil—Man characteristic of the present period.—59. Temporary existence of certain extinct genera and species.—60. Geological use of characteristic genera and species.—61. Examples—Trilobites characteristic of the Silurian strata.—62. Description of them.—63. Dr. Buckland's reflections on them.—64. Species characteristic of the lias—Ichthyosaurus.—65. Characteristics of the Wealden—Hylæosaurus—Iguanodon.—66. Characteristics of the chalk.—67. Ammonites, their distribution between the Silurian and chalk.—68. Fossil cephalopodes—Nautilus—Danians.—69. Fossil gasteropodes—Bigranulosa murchisonia—Cypræa elegans—Voluta elongata—Pterocera oceani.

46. A GENERAL idea of the series of stratified rocks, proceeding

downwards from the superficial soil, which is the theatre of agriculture, through the alluvial and diluvial deposits upon which it rests, and thence successively through the tertiary, secondary, and primary stratified rocks to the igneous ones which form the foundation of the terrestrial crust, may be formed from the following tabular statement (page 51), which we have compiled from the works of different geologists, and principally from that of Sir H. de la Beche, representing the order of the strata in Western Europe, and which in its general character will be found to correspond sufficiently with the condition of the terrestrial crust in most parts of the world, especially as regards its major divisions.

The strata, which in this table are denominated primary or palæozoic, are by some geologists included under the general denomination of secondary rocks. These must not be confounded with the igneous rocks, which are often called primitive rocks, and which are not stratified at all. The hypozoic or lowest beds of stratified rocks, together with the lower groups of the primary or palæozoic, are those which in the preceding paragraphs have been denominated transition or metamorphic rocks.

47. On contemplating the table, and on considering the peculiar super-structure which it exhibits, combined with the fact that each layer being a sedimentary deposit, must have been the result of an interval of time of considerable duration, two questions will naturally suggest themselves.

What are the dimensions of these several strata, and what the total thickness of the whole structure from the granite foundation on which it rests to the vegetable soil upon the surface, and what has been the probable interval of time required to produce each stratum.

Although certain and definite answers cannot be given to these questions, some degree of approximation may be made to them. The thickness of the several strata and groups of strata is subject to considerable local variation, nevertheless the indications of the limits of these variations in certain parts of the earth, which have been subject to geological survey of more or less accuracy may be useful.

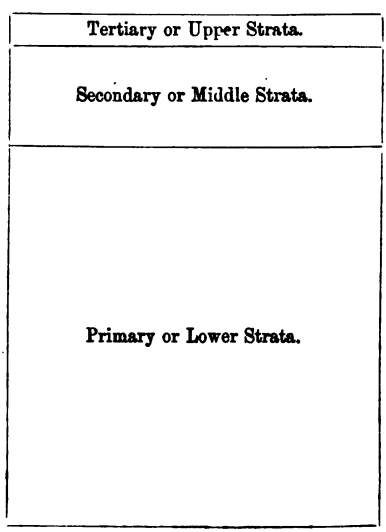
Thus, the following are the estimated thicknesses of several strata, proceeding upwards from the transition-system to the surface in Great Britain.

Gneiss system—a few miles.	
Mica schist system—from a few yards to a few miles.	
Cambrian system from one to five miles.	
Llandeilo formation	1200 feet.
Caradoc formation	2500 ,,

Tertiary or Cainozoic.		Mineral accumulations of historic period, Pleistocene, Pleiocene, Miocene, Eocene.
Secondary or Mesozoic.	Cretaceous.	Chalk of Maestricht and Denmark, Ordinary chalk with and without flints, Upper green sand, Gault, Shanklin sands, Vecten Neocomian or lower green sand, Wealden clay, Hastings sands, Purbeck series.
	Jurassic or Oolitic.	Portland oolite or limestone, Portland sands, Kimmeridge clay, Coral rag with its grits, Oxford clay with Kelloway's rock, Cornbrash, Forest marble and Bath oolite, Fullers' earth, clay, and limestone, Inferior oolite and its sands, Lias upper and lower with its intermediate marlstone.
	Triassic.	Variegated marbles, Muschelkalk, Red sand stone, grès bigarré, bunter sandstein.
Primary or Palæozoic.	Permian.	Zechstein, dolomitic and magnesian limestone, Lower new red, conglomerate and sandstones, Coal measures.
	Carboniferous Limestone.	Carboniferous and mountain limestone with its coal, sandstone, and shale in some districts, Carboniferous slates and yellow sandstones.
	Devonian.	Modifications of old red sandstone.
	Silurian.	Upper Ludlow rocks, Wenlock shale and limestone, Woolhope limestone, Middle Caradoc sandstone and conglomerate, Lower Landeilo, Bala and Snowdon beds.
	Cambrian.	Barmouth sandstone, Penrhyn slates, Longmynd rocks, and various rocks below the Silurian.
Hypozoic.	Mica Schist.	Beds of mica schist consisting of quartz and mica with or without feldspar or garnets, chloritic schist, talc schist, quartz rock, clay slate, limited beds of iron ore.
	Gneiss.	Beds of gneiss consisting of laminæ of quartz, feldspar and mica; beds of mica schist, quartz rock, limestone, hornblende schist.
Primitive or Igneous.	Syenite, Porphyry, Basalt, Porphyritic granite.	The relative position and age of these rocks is more or less uncertain, though it seems probable that they may stand in the order here assigned to them.
	Granite.	This system of igneous rocks descends to an undefined depth, and is assumed to rest upon the internal liquid nucleus of the globe.

Wenlock formation	1800	feet
Ludlow formation	2000	,,
Old red sandstone	1000	,,
Carboniferous or mountain limestone	1500 to 2500	,,
Millstone grit	500 to 700	,,
Coal formation	3000	,,
Lower new red Pontefract rock	100	,,
Magnesian limestone	300	,,
New red sandstone	1000	,,
Lias	1000	,,
Lower or Bath oolite	400 to 800	,,
Middle or coralline oolite	300 to 800	,,
Upper or Portland oolite	200 to 800	,,
Greensand formation	——	
Chalk formation	——	
Lower tertiary or eocene, about	1200	,,
Miocene formation.		
Pleiocene.		
Pleistocene.		

Rough as this approximation is, it may give some idea of the general thickness, at least, of the stratified part of the crust of the earth. It would appear from combining these results, that the total thickness of the stratified crust, as far as these observations go, varies from 10 to 20 miles. Of this thickness the lower, or palæozoic strata, constitute the principal part, as will be seen by the annexed diagram given by Professor Phillips.



48. To the question as to the lapse of time during which these successive sedimentary strata have been formed, it is impossible to give any answer even as definite as the estimates of their thickness. All that can be said is, that the deposition from turbid waters being generally a slow process, it may be imagined that intervals of time of vast duration must have been required for the formation of strata which measure many miles in thickness.

But besides the mechanical deposition of matters suspended in water, we find numerous traces of chemical decomposition, which could only have been effected in long intervals of time. Thus deposits of limestone lie in frequent alternation with sandstones and clays. These indicate a series of changes in the mode of action, by which the total stratified mass was produced, consisting of successive cessations and renewals in chemical and mechanical action.

In short all these effects combined with others, presently to be mentioned, lead to the conclusion that the period during which the human race and its contemporary tribes have existed upon the earth, is but a brief interval compared with the immense lapse of time occupied by the formation of the igneous rocks, by the cooling down of the superficial part of the fused matter, and the subsequent deposition of the stratified crust.

49. It may be useful here briefly to recapitulate the history of the globe, as we find it inscribed upon its crust.

Originally a mass of fluid matter, in a state of igneous fusion, it assumed the globular form in virtue of the mutual gravitation of its parts. Launched by the Creator into space with a motion of rotation round a certain diameter as an axis, it took the form of an oblate-elliptical spheroid, flattened at the poles, in virtue of the centrifugal force attending its rotation. The degree of spheroidal ellipticity being of course precisely that which corresponded to its velocity of rotation.

In this state its extremely exalted temperature would not only maintain the matter at its surface in a state of fusion, but would also keep a certain portion of the solid matter in a state of sublimation, and all the liquid matter in a state of vapour suspended in and mixed with the surrounding atmosphere.

After a continuance of greater or less duration in this state, the heat of the globe being continually radiated into the surrounding space, the temperature of its surface would be gradually diminished, and would, at length, fall below the point of fusion of the matter composing its surface, and consequently the superficial part would be solidified, and the globe would be coated, as it were, by a thin skin or shell of solid matter, enclosing within

it the matter still remaining in fusion. By the continued effect of radiation the temperature of the surface would continually decrease, and consequently the thickness of the solidified shell would be continually augmented. At length the superficial temperature would fall to such a point that the sublimated matter would be precipitated on the surface, and when the superficial temperature, falling still lower, would descend below the boiling point of water, a general condensation of the vapour sustained in the atmosphere would ensue, and the entire surface of the globe would be covered with an ocean of uniform depth.

If no disturbing force acted, this would have continued to be the condition of the globe; but the fused matter enclosed by the solid crust being subject to effects more or less irregular, and exercising unequal pressures, it was in some places protruded upwards, and in others depressed. In this manner certain parts of the solid crust were pushed above the level of the water, while others may have suffered corresponding depressions. Instead, therefore, of a universal ocean, the surface became diversified by land and water.

The action of the water upon the subjacent solid crust of the earth by erosion and disintegration and exposure to atmospheric action, produced various changes in its condition; and the parts thus washed off being subsequently deposited at the bottom of the waters, produced the incipient stratification which has been above described.

When the temperature of the globe was reduced to such a point as to be compatible with the existence of organised bodies, the first forms of life were called by the Creator into existence, and were such as were adapted to the then physical condition of the globe, being, as might be expected, exclusively marine tribes. When subsequently land emerged from the ocean, and by the condensation and precipitation of vapour rivers and lakes were formed, terrestrial, fluviatile, and lacustrine tribes were called into existence.

50. As each successive stratum was thus formed, the remains of the animals and vegetables of the epoch were deposited in them, and have accordingly been preserved to our times. Fluviatile and land animals, in greater or less numbers, were swept into the embouchures of rivers, and there deposited like the others. Lacustrine tribes were, in like manner, deposited in the bottoms of vast lakes or inland seas.

51. But, besides these, there are indications of other changes either gradual or sudden, which would explain the deposition of terrestrial organic remains in the strata. There are evidences that the swellings upwards and subsidence downwards of the

crust, by the internal movements of the fluid nucleus of the globe, caused various changes in the distribution of land and water, so that parts of the globe which at one time were raised above the waters, and inhabited by terrestrial tribes, were subsequently submerged; while other parts, being elevated, emerged from the waters and formed new continents or islands. Indeed, changes which are in actual progress, and which will be presently noticed more fully, show that such phenomena are still produced, though probably on a much smaller scale, than at the earlier stages of the growth of the earth when its crust, having less thickness and strength, offered less resistance to the internal movements of its fluid nucleus.

52. Since the strata were deposited during a succession of periods of long duration, each receiving the remains of the organised tribes which inhabited the earth at the period of its deposition, it follows that the organic contents of these successive strata may be regarded as so many museums presenting to us specimens of the zoology and botany of the globe at the successive periods of their deposition. By examining, therefore, these remains, we shall be able to compare with each other, and with the existing tribes, the living inhabitants of the globe at the several periods of the formation of these strata.

53. The first and most obvious inference suggested by such an analysis is, that the number and variety of organised beings has rapidly increased, from the period at which the earth became habitable to the present epoch. This is rendered evident by a comparison of the number of species found in a given thickness of strata, proceeding downwards from the surface, which has been estimated by Professor Phillips as follows:—

	Number of Species in 1000 feet thickness.
Tertiary	1410
Cretaceous	707
Oolitic	456
Triassic Permian	82
Carboniferous	47
Silurian	27

These numbers represent the relative proportion of marine species, by far the most numerous of the organic remains, more especially in the lower strata. This calculation was based upon the results of observations made about 1834, and consequently the numbers given are considerably below what would be obtained from more recent observation; but their proportion, which is all that concerns us here, would probably not be altered by subsequent results.

54. Since, therefore, it appears that the globe, through a long series of periods, has been tenanted successively by various races and tribes, both animal and vegetable, it is a question of profound interest to determine whether creative power, in the production of these organic beings, has operated upon the same principles which are manifested in the structure of its actual inhabitants. It might, for example, be imagined that the forms of life at those distant epochs, existing probably under extremely different physical conditions, might be totally different from, and utterly incomparable with, those which now prevail. Or though they might agree in certain general principles and conditions, they might be expected to exhibit extreme differences in many important details. A survey, nevertheless, of the existing tribes, and a comparison of them with the remains found in the terrestrial strata, lead to the conclusion, that though the former inhabitants of the globe differed from the present in many minute details of their structure, yet they agreed in all the more essential principles.

Naturalists have resolved the existing animal kingdom into four primary divisions: the *Vertebrates*, the *Articulated* or *Annulated*, the *Mollusca*, and the *Zoophytes*.

Quadrupeds, birds, and fishes, for example, are Vertebrated animals; insects, spiders, and certain shell-fish, such as crabs and lobsters, present examples of Articulated animals; snails and oysters are examples of Mollusca; and star-fish, sea-blubber, and corals, of the class of Zoophytes.

Now a due examination of the organic remains deposited in the terrestrial strata leads to the conclusion, that they admit of precisely the same general zoological division.

But the analogy between present and past creations is still closer when those primary divisions are resolved into several classes. Thus the living vertebrates are divided into mammifers, birds, reptiles, amphibia, and fishes. In like manner the fossil vertebrates admit of precisely the same classification. We find among them all these classes and no others.

Again, the living articulated animals are resolved into the subordinate divisions of insects, myriapodes, arachnida, crustacea, and worms of various forms. A like subdivision is applicable to fossil Articulata.

Fossil, like living, Mollusca are resolved into Cephalopodes, Gasteropodes (snails), Acephala (oysters and mussels), Bryozoaria (plumatella), and others. In fine, the Zoophytes, fossil as well as living, are resolved into Echinodermata (sea-urchin, star-fish), Polyparia (coral), Infusoria (monads), and Spongyaria (sponges), all of which are found reproduced in the fossil state.

55. But when we descend to more minute distinctions we cease

to find the same close correspondence. Genera or families of the above-mentioned classes are found among existing species which are altogether absent from the fossils; and, on the other hand, numerous genera of fossil animals have no place in the existing animal kingdom. Of about 1000 fossil genera, somewhere about 500 are identical with those of existing animals, the other 500 being extinct.

The difference between the present and past creations is, as may be expected, still more remarkable when we come to compare species with species. Thus of 10000 well-ascertained fossil species there are not more than 200 or 300 which still survive.

56. Though the counterparts of all the principal divisions of the animal kingdom are thus found in the fossil state, they are by no means equally distributed through the strata. Nature, on the contrary, seems to have called them successively into existence, according to their increasing perfection of organisation,—the Mammalia, the most perfect of all, being the most recent in date; and the Zoophytes and Mollusca, the lowest in their organisation, the earliest.

Thus the first forms of life which appeared during the Silurian period were chiefly confined to the Zoophytes and other classes of the lowest organisation, the only Vertebrates then existing being fishes, and those in very limited numbers. The same forms, for the most part, prevailed upon the globe during the Devonian and Carboniferous periods. During the Permian and Triassic periods animated nature received no other increase than that of a few reptiles. No other classes were added to the creation during the long interval of the Oolitic period; but the number of species of reptiles, as of all the other classes just mentioned, were considerably increased.

The first appearance of birds was manifested during the Cretaceous period, but they were very limited in number until the Tertiary period.

It was not till the Tertiary period which immediately preceded the present epoch that Mammalia were created. Birds, reptiles, and fishes augmented in number and variety also during this period, as did various others of the inferior classes, such as Gasteropodes and Acephala.

It must be observed, however, that foot-prints of some Mammalia have been discovered in the Oolitic strata, and marks, supposed to be those of birds, in the Triassic.

57. In the following table, compiled from the very extensive tables of Paleontology, which accompany the work of Professor d'Orbigny, we have exhibited the commencement, continuation, and prevalence of the different classes of animals which inhabited

the earth during the successive periods from the Silurian to the Human. The relative numbers of each class prevailing at the different periods are indicated by the four following signs:

∴ least.
× more numerous.
△ still more numerous.
⊙ most numerous.

Classes.	Silurian.	Devonian.	Carboniferous.	Permian.	Triassic.	OOLITIC. Early.	OOLITIC. Middle.	OOLITIC. Late.	CRETACEOUS. Early.	CRETACEOUS. Middle.	CRETACEOUS. Late.	TERTIARY. Early.	TERTIARY. Middle.	TERTIARY. Late.	Human Period.
Polyparia	∴	∴	∴	∴	∴	∴	×	×	∴	×	∴	∴	×	∴	⊙
Crinoidea	△	△	⊙		∴	∴	×	∴	∴	∴	∴	∴	∴	∴	∴
Ophiuroidea, Asteroidea, Echinoidea, Echinodermata	∴	∴	∴	∴	∴	∴	×	∴	∴	×	△	×	×	×	⊙
Bryozoaria	∴	×	×	∴	∴	∴	△	∴	×	△	⊙	×	△	×	△
Brachiopoda	△	⊙	△	×	×	∴	×	∴	△	△	△	∴	∴	×	∴
Acephala	∴	∴	∴	∴	∴	×	×	×	×	△	△	△	△	△	⊙
Marine Gasteropodes	∴	∴	×	∴	∴	∴	×	∴	×	×	×	△	△	△	⊙
Fluviatile Acephala								∴				×	×	×	⊙
Terrestrial and Fluviatile Gasteropodes									∴	∴	∴	△	△	△	⊙
Acetabuliferous Cephalopodes					∴	∴	×	∴	∴	∴	∴	∴	∴	∴	⊙
Tentaculiferous Cephalopodes	⊙	△	△		∴	∴	∴	∴	△	×	△	∴	∴	∴	∴
Fishes	∴	∴	×		∴	∴	×	∴	∴	∴	×	△	×	∴	⊙
Reptiles				∴	×	∴	△	∴	×	∴	∴	∴	×	×	⊙
Birds					?				∴		∴	∴	∴	×	⊙
Mammalia							?					∴	∴	×	⊙

58. It appears that the creation of fishes, reptiles, birds, and mammalia, the four vertebrated classes, underwent a sudden and large augmentation at the epoch of transition from the tertiary to the human period, and that, to crown all, man appeared for the first time in the period to which he has given his name. Among the infinite variety of fossils discovered in the strata of the earth, there is no instance of human remains.

59. Although the various classes of animals and vegetables, when once called into existence, have continued to prevail upon the earth till the present time, the same is not true of the genera constituting these classes, and still less of the species of these genera, as already mentioned. Species appear in particular strata, no trace of which is found in any other, superior or inferior. The inference is, that such animals existed only during the period corresponding to the deposition of these particular strata.

It happens sometimes that particular species prevail through certain groups of strata, superposed in regular order, but totally disappear from all subsequent and antecedent. Such species are accordingly characteristic, not indeed of particular strata, but of those limited groups of strata in which they prevail, and the inference is, that they had continued to exist upon the earth during the period corresponding with the deposition of the groups, but did not exist there before or after.

60. The species which thus prevailed upon the earth during geological periods more or less limited, and which ceased to exist before the period marked by the presence of the human race, have accordingly supplied to the geologist tests for the identification of strata much more determinate than any which depend on their mineral constituents. When the presence of a particular species is strictly limited to particular strata, it becomes an unerring test of the presence of that stratum wherever this species is found. If it has prevailed through groups of strata, it is a test, though not of particular strata, still of the group to which its presence is limited.

61. Numerous examples of these characteristic species may be mentioned. A certain family of Crustacea, called TRILOBITES, are almost exclusively limited to the Silurian period, appearing rarely in the lower bed of the carboniferous limestone, and never above them.

62. The Trilobites consisted of an oblong body, divided transversely into three parts, and also longitudinally into the same

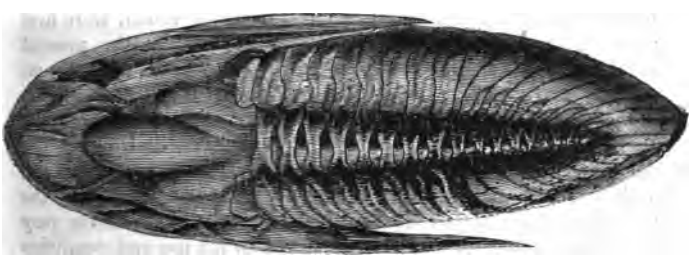


Fig. 6.—(Trilobite) Ogygia Guettardi.

number of lobes. The comparison of the forms of these animals with those of existing Crustacea, renders it probable that they dwelt in the depths of the sea, far from coasts, floating on their back, and never resting, inasmuch as their feet could not retain them stationary, and movement was necessary for their respiration. From a peculiarity of the mouth, it is inferred that they were carnivorous, preying probably on naked Mollusca or

Annelida, with which their remains are found associated. But one of the most interesting facts connected with them is the structure of their eyes, which resemble those of insects described in our Tract on "Microscopic Drawing." They consist of a vast number of minute lenses of octagonal form, set in the ends of tubes arranged side by side, so as to produce a radiating mass of eyes, enabling the animal to look at the same time in every direction. As many as four hundred of these lenses have been found set in a single cornea.

63. Such a structure proves, if proof were wanted, that the properties of light, and of the transparent media constituting the atmosphere and water, were, at the remote epochs when the earth was tenanted by those creatures, what they now are. "With respect to the waters," says Dr. Buckland, in reference to these creatures, "we conclude that they must have been pure and transparent enough to allow the passage of light to organs of vision, the nature of which is so fully disclosed by the state of perfection in which they are preserved. With regard to the atmosphere, also, we infer, that had it differed materially from its actual condition, it might have so far affected the rays of light that a corresponding difference from the eyes of existing Crustaceans would have been found in the organs on which the impressions of such rays were then received. Regarding light itself, also, we learn, from the resemblance of these most ancient organisations to existing eyes, that the mutual relations of light to the eye, and of the eye to light, were the same at the time when Crustaceans, endowed with the faculty of vision, were first placed at the bottom of the primeval seas, as at the present moment. Thus we find among the earliest organic remains, an optical instrument of most curious construction, adapted to produce vision of a peculiar kind, in the then existing representatives of one great class in the articulated division of the animal kingdom. We do not find this instrument passing onwards, as it were, through a series of experimental changes, from the more simple into more complex forms: it was created, at the very first, in the fulness of perfect adaptation to the use and condition of the class of creatures to which this kind of eye has ever been, and is still, appropriate. If we should discover a microscope, or telescope, in the hand of an Egyptian mummy, or beneath the ruins of Herculaneum, it would be impossible to deny that a knowledge of the principle of optics existed in the mind by which such an instrument had been contrived. The same inference follows, but with cumulative force, when we see nearly four hundred microscopic lenses set side by side in the compound eye of a fossil trilobite; and the weight of the argument is multiplied

a thousand-fold, when we look to the infinite variety of adaptations by which similar instruments have been modified, through endless genera and species, from the long-lost Trilobites of the transition strata, through the extinct Crustaceans, and the countless hosts of living insects. It appears impossible to resist the conclusions as to unity of design in a common Author, which are thus attested by such cumulative evidences of Creative Intelligence and Power; both as infinitely surpassing the most exalted faculties of the human mind, as the mechanisms of the natural world, when magnified by the highest microscopes, are found to transcend the most perfect productions of human art."

64. In like manner the lias, which is the earliest deposit of the Oolitic period, is characterised by various organic remains, as well of reptiles as of mollusca and the lower divisions. Among the latter may be mentioned a particular species of Ammonites, called the Ammonites Bucklandi, and among the former the ichthyosaurus,

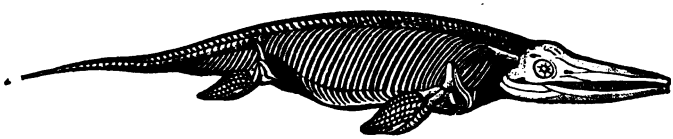


Fig. 7.—The Ichthyosaurus.

or fish-lizard, is an example of an extinct animal of this tribe, which has the muzzle and general aspect of a porpoise, the head of a lizard, the teeth of a crocodile, the vertebræ of a fish, the sternum or breast-bone of an ornithorhynchus, and the fins of a whale. The enormous magnitude of the eyeballs was one of the peculiarities of this genus. The cavities in which they were lodged, in one of the species, measured not less than fifteen inches in diameter. A ring of bony plates surrounded the socket, which apparently seemed to protrude more or less the globe of the eye, and vary the convexity of the cornea, so as to adapt the organ for near or distant vision. This, combined with the great power of the fins or propellers, must have conferred upon the reptile great promptitude in perceiving and seizing its prey.

These reptiles were essentially aquatic, and the form of their teeth proves them to have been carnivorous. Their coprolites, or fossilised excrements, show that their intestine was spirally arranged, like that of certain fishes.

65. The Wealden strata, lying near the upper part of the oolitic and the lower part of the cretaceous, is characterised by remains of the Monocotyledonous * division of plants, by ferns, by various

* Having only one seed-lobe.

tribes of the lower animals, by insects, fishes of the genus Lapidotus, and, among the colossal class of reptiles, by the Hylæosaurus, and among terrestrial quadrupeds, by the Iguanodon.

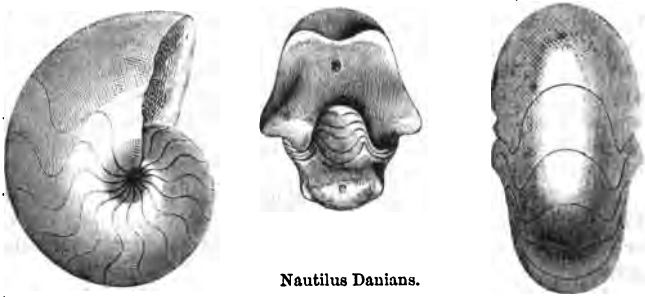
66. Among the numerous animals characteristic of the Cretaceous period may be mentioned the Mososaurus of Hoffman, the Belemnites mucronatus, the Terebratula plicatilis.

67. In cases where a group of strata is characterised by the prevalence of a particular family of fossils, which first appear at its

Fig. 8.—Ammonites Humpriasiamus.

lowest, and finally disappear at its uppermost layer, the succeeding strata are often distinguishable one from another, by the prevalence in them of a different species of this generic family. Thus

Fig. 9. Fig. 10. Fig. 11.



Nautilus Danians.

for example, the Ammonites, so called from their spiral form, resembling the horn sculptured on the head of Jupiter Ammon, commence in the Silurian and finally disappear after the chalk.

But each stratum, from that in which the family first appears

to that in which it disappears, is distinguished by the presence of a peculiar species. Of 222 species of Ammonites 17 belong to the oldest fossiliferous rocks, 7 to the carboniferous system, 15 to the new red sandstone, 137 to the oolite, and 47 to the chalk.

68. Among the organic remains characteristic of strata or groups of strata, the following examples may be mentioned: Fossil Cephalopodes are exceedingly numerous in the palæozoic group; but of all the genera hitherto discovered, one only, that of the nautilus, has come down to the present times.

These fossils appear in great numbers in the lower strata of the secondary rocks, are few in the lias and oolite groups, re-appear in great numbers again in the cretaceous, and nearly disappear from the tertiary rocks.

The examples are so numerous, and preserved in such perfection, that it is difficult to select any in preference to another, as illustrations of their forms. The nautilus, the only surviving genus of the Tentaculiferous Cephalopodes in the first periods of animal life, had nearly the form which it still retains.

Fig. 12.—Murchisonia Bigranulosa.

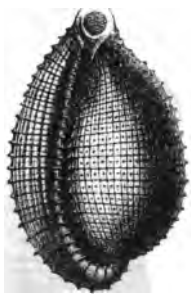


Fig. 13.—Cypræa Elegans.

69. Fossil Gasteropodes are, like the Cephalopodes, extremely numerous. The terrestrial and fluvial genera have in general appeared for the first time in the Tertiary period; but marine

genera have been found in all the rocks from the Silurian upwards, and in gradually increasing numbers. They were, therefore, among the earliest manifestations of animal life on the globe; and what is remarkable is, that most of the genera, including even those of the Silurian period, still survive.

The close analogy of these ancient forms with the existing species will be manifest, by some examples taken from among the countless numbers of fossil shells collected by geologists.

A fossil shell from the Permian group is shown in fig. 12, and one found in all the tertiary beds, in fig. 13.

One of the genera which first appears in the middle strata of

Fig. 14.—Voluta Egata.

the cretaceous group is shown in fig. 14, and one which begins in the middle of the oolite, in fig. 15.

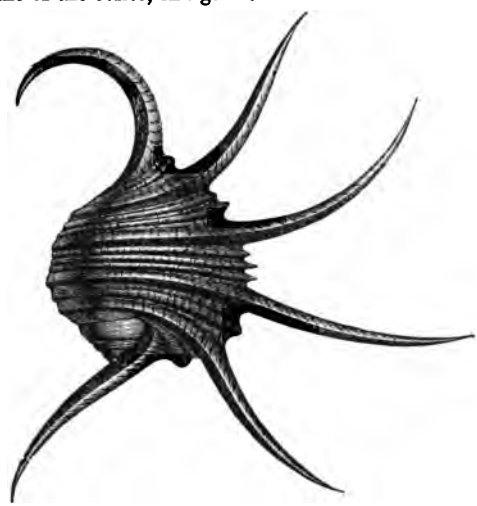


Fig. 15.—Pterocera Oceani.

Fig. 66.—BARREN ISLAND IN THE BAY OF BENGAL.

THE CRUST OF THE EARTH;

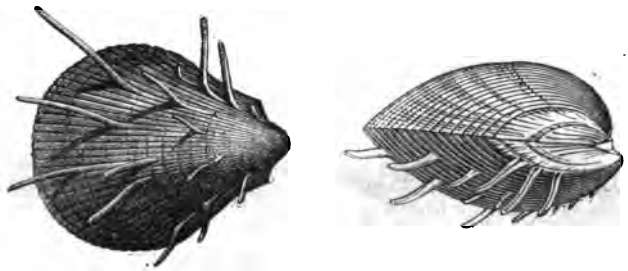
OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER III.

70. Spondylus.—71. Pentamĕrus.—72. Reticulipora.—73. Ceratites.—74. Enormous masses of animal remains forming entire islands and continents — Ehrenberg's discoveries.—75. Dr. Mantell's table of organic strata.—76. Forms of life in the Silurian period.—77. Sir R. Murchison's observations on the changes of the forms of life from period to period.—78. Stratification in undisturbed plains horizontal.—79. Strata thrown into oblique positions by disruption of igneous rocks.—80. Formation of mountains.—81. Arrangement of strata on their flanks.—82. Strata sometimes upheaved without being disrupted.—83. Sometimes disrupted.—84. Sedimentary strata deposited subsequently to disruption — discordant stratification.—85. How these supply data for determining the epoch of the disruption.—86. Determination of the relative ages of mountains—Cumbrians and Grampians much older than the Alps.—87. How inclined strata have enabled geologists to analyse the structure of the terrestrial crust to the level of the igneous rocks.—88. Erosion of stratification by the action of water, and the subsequent deposition of other strata.—89. Basalts—their character and composition.—90. Various forms of basaltic rocks.—91. Their extensive diffusion over all parts of the earth.—92. Their columnar structure—Giant's Causeway.—93. Basaltic causeway of the Volant—Dykes and colonnade of Chenavari.—94. Veins of basalt.—95. Basalts in mounds.—96. Basaltic grottoes—Kase grotto of Bertrich-Baden—Fingal's Cave.—97. Trachytic rocks.—98. Trachytic mountains.—99. Their origin igneous.

70. The Spondylus, figs. 16, 17, of which there are forty-five

Fig. 16. Fig. 17.

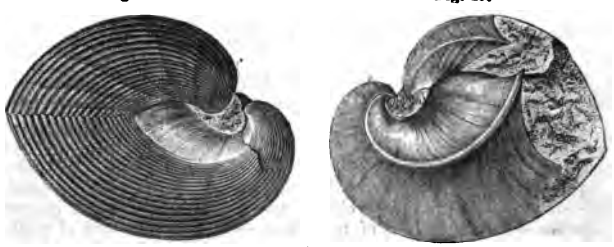


Spondylus Spinosus.

fossil species, first appears in the lowest stratum of the cretaceous group, and presents an example of the fossil Lamellibranchiæ.

71. The Pentamerus, figs. 18, 19, of which there are twenty-one fossil species, is an example of the Brachiopoda. This is

Fig. 18. Fig. 19.



Pentamerus Knightii.

first seen in the lowest strata of the silurian group, and becomes extinct after the Devonian period, so that its existence was limited to the earliest epochs of animalisation.

72. The Reticulipora, figs. 20, 21, 22, 23, an example of the Bryozoares, is an extinct genus Retepora, of which there are five fossil species known; the first in the middle strata of the oolites, and the others in the upper strata of the cretaceous group. In this the meshes are formed of high vertical laminæ, supplied with cells by transverse lines on each side; fig. 20 shows the whole in its natural size; fig. 21, the external part magnified; fig. 22, the internal part magnified; fig. 23, the laminæ as shown with a still higher magnifying power.

73. The Ceratites belong to the family of the mollusca called Bacculine, the only known species of them found in the lowest strata of the cretaceous system.

Fig 20.

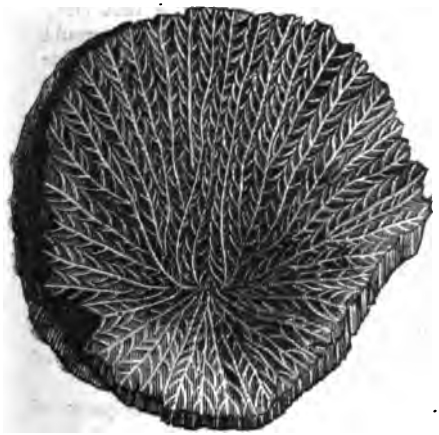


Fig. 22.

Fig. 21.

Fig. 23.

Reticulipora obliqua.

74. Among the most wonderful results of the animalisation of the earth, in the remote geological periods, is the enormous extent of matter which various species of animals elaborated from the gaseous or liquid element around them, by vital action, and which have remained as a perpetual record of their presence. Whole islands, and even continents, have been produced by the secretive functions and other vital agencies of countless myriads

of these living instruments. Ehrenberg, the celebrated Prussian microscopist and naturalist, mentions a stratum in Germany, not less than 14 feet in thickness, composed exclusively of the shells of animalcules, so minute that forty thousand millions of them would not fill a space greater than a cubic inch. Mountains, hundreds and even thousands of feet in height, are found to be composed exclusively of organic matter. The strata of vegetable origin are not less extensive, consisting of forests engulfed by the subsidence of vast tracts of land, or embedded in the mud of rivers and estuaries, of lignite and brown coal in the tertiary deposits, of coals and shales in the carboniferous strata, and of silicified and calcified trunks of trees in the tertiary and secondary formations.

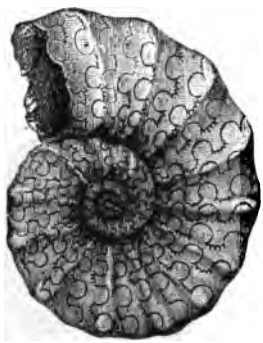


Fig. 24.—Ceratites Nodosus.

75. But the strata which consist wholly or principally of animal remains are so numerous, and of such vast extent, that, as Dr. Mantell observed, the exclamation of the poet may be reiterated by the philosopher,

"Where is the dust that has not been alive?"

for there is not an atom in the superior strata of the crust of the globe that has not probably passed through the complex and marvellous laboratory of vitality.

The various families of animals from the infusoria and zoophytes, up to man himself, have then contributed more or less, by their organic remains, to form the solid crust of the globe. The following table, taken from the work of Dr. Mantell, presents a concise view of some of the most obvious examples of these remarkable deposits.

Rocks Composed wholly or partly of Animal Remains.

Strata.	Prevailing Organic Remains.	Formations.
Trilobite schist	Trilobites	Silurian system.
Dudley limestone	Corals, crinoidea, crustaceans, shells, &c.	,,
Shelley limestone	Brachiopodous shells	,,

TABLE OF FOSSIL MINERALS.

Rocks Composed wholly or partly of Animal Remains.

Strata.	Prevailing Organic Remains.	Formations.
Mountain limestone	Corals and shells	Carboniferous system.
Encrinital marble	Crinoidea and shells	,,
Mussel-band	Fresh water mussels	,,
Ironstone nodules	Trilobites, insects, and shells	,,
Lias-shales and clays	Pentacrinites, reptiles, fishes	Lias.
Limestone	Terebratulæ, and other shells	,,
Lias conglomerates	Fishes, shells, corals	,,
Gryphite limestone	Shells, principally gryphites	,,
Shelley limestone	Terebratulæ, and other shells	Inferior oolite.
Stonesfield slate	Shells, reptiles, fishes, insects	Oolite.
Pappenheim schist	Crustacea, reptiles, fishes, insects	,,
Bath stone	Shells, corals, crinoidea, reptiles, fishes	,,
Ammonite limestone	Shells of cephalopoda, principally ammonites	,,
Coral rag	Corals, shells, echini, ammonites	,,
Bradford limestone	Crinoidea, shells, corals, cephalopoda	,,
Portland oolite	Ammonites, trigoniæ, and other shells	,,
Purbeck and Sussex marble	Fresh water-shells and crustacea	Wealden.
Wealden limestone	Cyclades and other fresh-water shells, crustacea, reptiles, fishes	,,
Tilgate grit (some beds)	Bones of reptiles, fishes, fresh-water shells	,,
Farringdon gravel	Sponges, corals, echini, and shells	Green sand.
Jasper and chert	Shells	,,
Green sand	Fibrous zoophytes	,,
Chalk	Polythalamia and other animalcules	Cretaceous.
Maestricht limestone	Corals, shells, ammonites, belemnites, and other cephalopoda, reptiles	,,
Hippurite limestone	Shells, principally hippurites	,,
Hard chalk (some beds)	Echini and belemnites	,,
Flints	Sponges and other fibrous zoophytes; infusoria, &c., echini, shells, corals, crinoidea	,,
Limestone	Fresh-water shells	Tertiary.
Nummulite rock	Nummulites	,,
Septaria	Nautili, turritellæ, and other shells	,,
Calcaire grossier	Shells and corals	,,
Gypseous limestone	Bones of mammalia (Palæotheria, &c.), birds, reptiles, fishes	,,

Rocks Composed wholly or partly of Animal Remains.		
Strata.	Prevailing Organic Remains.	Formations.
Lacustrine marl	Cyprides, phryganea, fresh-water shells	Tertiary.
Monte Bolca limestone	Fishes	,,
Bone-breccia	Mammalia, and land shells	,,
Sub-Himalaya sandstone	Bones of elephants, mastodons, reptiles, &c.	,,
Tripoli	Infusoria	,,
Semiopal	Infusoria	,,
Richmond earth	Infusoria	,,
Guadaloupe limestone	Human bones, land shells, and corals	Human epoch.
Bermuda limestone	Corals, shells, serpulæ, infusoria	,,
Bermuda chalk	Comminuted corals, shells, &c.	,,
Bog iron ochre	Infusoria	,,
Siliceous limestone		Tertiary.

Even in this list, extensive as it is, numerous strata in which animal remains largely predominate, have been omitted. In the tertiary and more recent deposits, every order of existing animated nature is found. The bones of man, however, are confined to the superficial part, which has been formed since the globe was peopled by the races which now inhabit it.

76. How completely changed the inhabitants of the earth have been from one geological period to another, may be inferred from the following observations of Sir R. Murchison. "Beginning," says he, "with the *vertebrata*, are not the fishes of the old red sandstone as distinct from those of the carboniferous system, on the one hand, as from those of the Silurian on the other? M. Agassiz has pronounced that they are so. Are any of the *crustaceans*, so numerous and well defined throughout the Silurian rocks, found also in the carboniferous strata? I venture to reply, not one. Are not the remarkable *Cephalopodus mollusca*, the *Phragmoceras*, and certain forms of *Lituites*, peculiar to the older Silurian system? Is there one species of the *Crinoidea* figured, known in the carboniferous strata? Has the *Serpuloides longissimus*, or have those singular bodies the *Graptolites*, or, in short, any zoophytes of the Silurian system been detected in the well-examined carboniferous rocks? And in regard to the corals, which are so abundant, that they absolutely form large reefs, is not Mr. Lonsdale, who has assiduously compared multitudes of specimens from both systems, of opinion, that there is not more than one species common to the two epochs?"

77. These anticipations of Sir R. Murchison have been more than realised by the subsequent researches of M. D'Orbigny, founded upon his own observations, which extended over a large portion of the New as well as of the Old world, and upon the entire mass of facts connected with the analysis of the crust of the earth collected by the observations of the most eminent geologists in all parts of the world. It appears from these researches, that during the long series of periods of geological time from the first appearance of organised life upon the globe, to the period in which the human race and the contemporaneous tribes were called into existence, the world was peopled by a series of animal and vegetable kingdoms, which were successively destroyed by violent convulsions of the crust, which produced as many devastating deluges. The remains of each of these ancient creations are deposited in a series of layers or strata one over the other; and from an examination of them it has been found that each successive animal kingdom was composed of its own peculiar species which did not appear in any posterior or succeeding creation, but that genera once created were frequently revived in succeeding periods; that many of these genera, however, became extinct long before the arrival of the human period; that during the human period no new genus was called into existence, except that of the human race, which, however, according to the idea of the most eminent naturalists, ought to be regarded as an order rather than a genus.

Each of the succeeding animal kingdoms which thus temporarily inhabited the earth consisted of many hundred species. Thus it has been ascertained by M. D'Orbigny, that there are deposited in the Cambrian or Lower Silurian strata not less than 418 species of the animals which inhabited the globe in the first period of its animalisation, and that these included specimens of all the principal divisions of animals from the Vertebrata downwards.

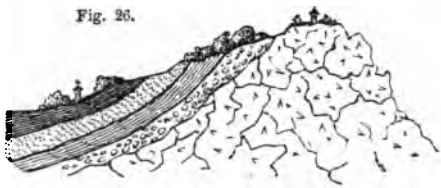
It will be sufficient, however, for the present, thus briefly to indicate these important discoveries, which we shall develop much more fully in the next volume of these series.

78. As already explained, the strata, when originally deposited, must in all cases have had a horizontal position, and they must succeed each other in their normal order, whenever the part of the earth at which they lie has undergone no disturbance subsequently to the date of their deposition, which has sometimes been the case with extensive plain countries. In such cases, therefore, a section of the crust would exhibit them in parallel and horizontal layers, as in fig. 25.

Fig. 25.

79. In undulating and mountainous countries it is found, however, that, instead of being horizontal, they are variously

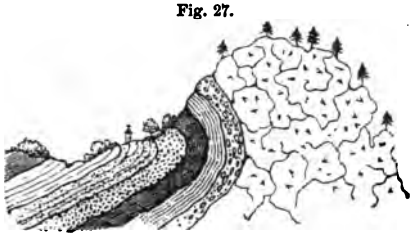
Fig. 26.



inclined (fig. 26), and sometimes bent into, or even beyond, the vertical direction (fig. 27).

When it is considered that at the time of their deposition the strata must have been horizontal, it will be evident that the position shown in these figures could only have been given to them by a force acting from below, by which they were heaved upwards, and by which the crust was broken, the igneous rocks having forced themselves through it.

Fig. 27.



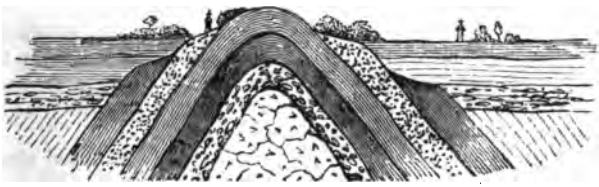
80. In such cases hills or mountains of greater or less elevation are formed, at the summits of which the igneous rocks which have been protruded through the stratified crust are at the surface, and the edges of the strata thus broken are ranged along the flanks, the lowest or most ancient being nearest the summit, and the others succeeding each other in their proper order in descending towards the adjacent valley or plain.

81. It will be evident that the stratum whose edge is highest on the mountain is that which lies the lowest on the plain, and that whose edge is lowest on the mountain is that which is highest or nearest the surface on the plain.

82. In the cases here exhibited the igneous rocks have split the stratified crust and broken quite through it. This, however, is not always the case. It often happens that the uplifting force loses its energy before the superincumbent strata are cracked, in which case they would cover the elevation preserving the order of their superposition, but would be, as before, inclined in accordance with the declivity of the hill produced by the uplifting force.

83. In other cases the superior strata, but not the inferior, are broken through, as shown in fig. 28. The edges of the disrupted

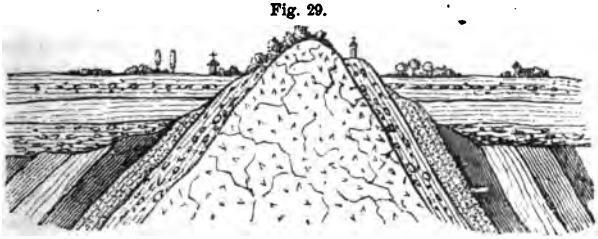
Fig. 28.



strata are then exposed upon the flanks of the elevation, and are ranged as above described; while the inferior strata, not disrupted retain their natural order upon the summit.

In other cases (fig. 29) the disruption is complete, and the

Fig. 29.



broken strata are ranged on each of the opposite declivities in the same order as already described.

84. It happens often that after the cessation of the disturbing force, by which the strata have been uplifted, the land having been again submerged, new depositions take place, the strata of which are of course horizontal and superposed upon those rendered oblique by the previous disturbance. This sort of superposition of strata is called by geologists discordant or unconformable stratification, and wherever it occurs it affords evidence of the action of a disturbing force from below, the geological date of which can be determined with more or less precision by a due examination and comparison of the superposed strata.

Cases of this kind of discordant stratification are shown in fig. 28 and fig. 29, in both of which horizontal strata deposited upon the oblique strata, are disposed along the slopes of the elevation.

85. It is evident that the epoch of the action of the disturbing force must, in all cases, have been posterior to that of the deposition of the inclined, that is, of the disturbed strata. It is equally apparent that the disturbing action must have ceased before the

deposition of the lowest of the superincumbent horizontal strata. The date of the disruption is therefore fixed geologically at some period between those of the deposition of the two strata just mentioned. Now whenever it so happens that the lowest, and, therefore, the first deposited of the horizontal strata, stands the next in order above the highest of the inclined strata in the geological scale, the date of the disruption is geologically fixed, being at the epoch between the deposition of two strata which follow each other in immediate succession.

But if, as often happens, the lowest of the horizontal strata hold a place in the geological scale separated from the highest of the inclined strata by several intermediate layers, which are locally absent, then the date of the catastrophe becomes more uncertain, inasmuch as it may have taken place at any epoch between those of the depositions of the highest of the inclined and the lowest of the horizontal strata.

86. Nothing is more beautiful or conclusive than the reasoning by which the geological dates of mountain-ranges have been determined by these means. One of the most interesting consequences resulting from the observation of such discordant stratifications as are here described, is the means they afford geologists of determining the relative ages of different ranges of mountains. Thus, for example, it is easily demonstrated that the mountains of Cumberland, Lammermuir, and the Grampians were raised above the surface of the ocean long before the Alps had burst the crust of the earth, and before even the continent of Europe was dry land. An examination of the slopes of these British ranges shows that the strata dislocated and inclined are those of the old slate and limestone, while the level strata superposed upon them in the adjacent plain are the more recent ones of the red sandstone. It follows that these ranges were raised above the waters posterior to the epoch of the deposition of the old slate and limestone, but antecedently to that of the red sandstone; and since the red sandstone has been deposited horizontally along their base, it follows that the land surrounding them was covered with water subsequently to their elevation.

An examination of the Alps gives a very different result. On the flanks of these mountains the tertiary strata are found inclined, sloping downwards, until they become level upon the general surface of Europe. It follows, therefore, that the date of the disruption to which the Alps owe their elevation was posterior to the deposition of the tertiary strata upon the European continent, while the elevation of the British ranges above mentioned was anterior to the deposition of the red sandstone; from which it follows that the Grampian, Lammermuir, and Cumbrian

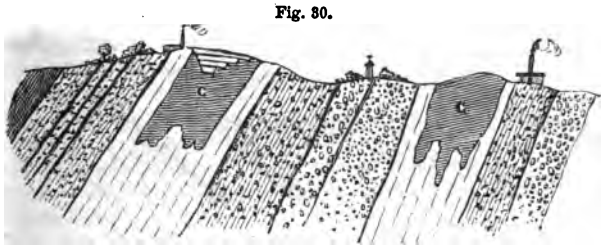
mountains were dry land, while the greater part of the continent of Europe was covered by the ancient ocean, and long before the Alps were reared above its surface.

In a subsequent tract this subject of the relative ages of the mountain system will be more fully developed.

87. From what has been here explained, and from inspection of figs. 26 to 29, the manner in which geologists have been enabled to analyse the crust of the earth to depths far exceeding any which could be reached by direct excavation, mining, or boring, will be easily understood. Nature herself, by these prodigious disruptions, has exposed to view the structure of the sedimentary strata in all cases where no subsequent deposition has taken place over them. By such disruptions it often happens that the strata are inclined over a large extent of country, the surface of which, intersecting their planes at a very oblique angle, is necessarily formed by the section of the strata in the order of their superposition, the breadth of the several sections being so much the greater, the more oblique the angle formed by the horizontal plane with the planes of the strata.

In fig. 30 the strata are represented inclined very slightly from

Fig. 30.

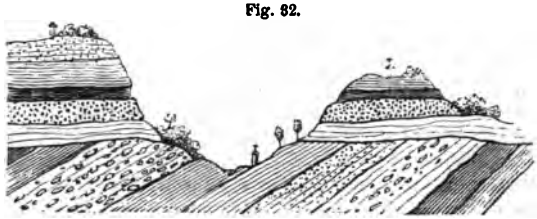


the perpendicular, and consequently the breadth of each stratum at the surface is very little greater than its actual thickness; but it will be easily understood that if the obliquity of the strata to a level plain were greater, a very thin stratum would present at the surface a considerable breadth. Supposing then the complete series of strata in any tract of country to be inclined at a very oblique angle to the level plain, it will be easily understood that in travelling in a direction at right angles to the lines of intersection of the strata with the surface, the succession of strata may be examined, and a much greater extent of their thickness submitted to observation, than could be accomplished by any artificial sections of horizontal strata.

88. Among the indications afforded by discordant stratifications of past convulsions to which the land has been subject, are some

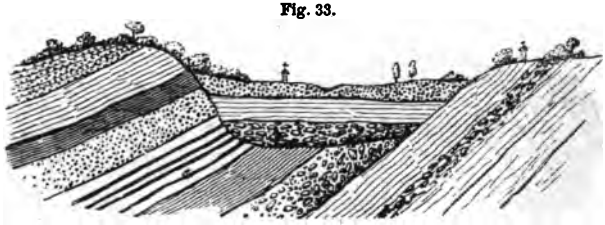
which show that, by the violent agitation of the waters consequent on sudden changes of level of their bed, and of the parts of continents over which they have swept, strata already formed have been partially broken up and carried away by currents. Excavations, such as that represented in fig. 32, are explained in this manner.

Fig. 32.



In such cases it has often happened that the waters under which such broken strata were submerged, having again become tranquil, a new series of strata have been deposited horizontally, filling up the excavation thus formed, as shown in fig. 33.

Fig. 33.



89. Closely allied with the matter ejected from volcanoes are the Basaltic deposits, which form so grand a feature in the scenery of many countries with which travellers are familiar.

All the circumstances and characters which attend these rocks conspire to show that they have issued from openings in the crust of the earth in a state of fusion much more complete than that of volcanic lava, and in the process of cooling have, in many cases, been crystallised, so as to assume those remarkable varieties of the columnar form, so conspicuously developed in the north of Ireland, the Scottish Islands, and many other parts of the world.

The Basaltic rocks are characterised by a dark colour and a compact base of the mineral called *Labradorite*, including black pyroxene, generally the magnetic oxide of iron, frequently peridote, and sometimes crystallised feldspar, to which they owe their porphyritic structure.

90. The fluid basalt often assumes the form of prismatic columns in the process of crystallisation, consequent upon slow cooling. Mr. Gregory Watt imitated this artificially by reducing 7 cwt. of Dudley basalt to fusion and causing it to cool slowly, when globular masses were formed, which gradually enlarged and pressed one against the other, until they forced themselves into regular columns, resembling in all respects those of natural basalt.

In some places basalt forms vast plateaux of considerable thickness, in others it is found in detached sheets of less extent, at points of mountains, more or less distant one from the other, and at the same level, as if it had originally been a single sheet and had been disrupted, by the convulsions of which the mountains have been the result.

In some cases the basalts form isolated masses or mounds rising in the midst of plains, altogether removed from all similar formations. They are also often found in veins in the strata of the earth, like those of minerals. They sometimes also present themselves as extensive walls, or in a series of separate mounds having a common direction. When basaltic rocks are presented in the form of sheets or mounds, the upper part is generally composed of porous cellular scoriform matter, irregularly divided, and terminated below by a plane surface, sensibly horizontal. When the mass is composed of several layers, these layers are separated one from another generally by thin beds of rapilli.*

91. Basaltic deposits are much more extensively scattered over the surface of the globe than those of ordinary volcanic origin. Unlike volcanic products, they are not confined to particular centres of action, but appear to have been produced wherever the terrestrial crust, yielding to the pressure from below, was rent so as to give issue to the fused matter. In the British Isles basaltic products are found in various places, and more particularly in the north of Ireland and Scotland. In France they are found everywhere from the northern part of Auvergne to Montpellier, and even to Toulon. On the borders of the Rhine they extend from the Ardennes to Cassel, and are continued eastward into Saxony, Bohemia, and the surrounding countries. They prevail to a great extent in Iceland, are recognised in the West India Islands and St. Helena, in the island of Ascension, and in almost all the islands of the southern ocean.

92. The tendency of these rocks to form themselves into prismatic columns has more especially excited the attention of the curious. In some cases all the prisms converge to the summit of

* Volcanic dust.

a mound, which thus assumes a sheaf-like structure. In others they take the form of close columns with the most picturesque aspect. In others again, these columns, cut off at a certain level, form a sort of mosaic pavement, to which the name of causeway has been given. Of this one of the most magnificent examples is presented in the case of the Giant's Causeway, in the north of Ireland.

93. Examples of similar formations are presented in different parts of Europe, and especially in the Vivarais, in the department of Ardèche, in France. A remarkable series of basaltic causeways is there presented on the banks of the river Volant, between Vals and Entraignes, a view of which is given in fig. 31, p. 33. The colonnades of Chenavari, near Rochemaure, fig. 34, and the dykes which are near the same place, fig. 35, present examples of other varieties of basaltic forms.

94. Basaltic rocks, having all the prismatic characteristics above described, are frequently presented in the form of mineral veins. Examples of this are found in the central parts of France, and also on the borders of the Rhine. Most commonly the matter composing the vein is compact or divided by irregular cleavage, but it also sometimes exhibits the prismatic form, the axis of the prisms being horizontal, fig. 36.

95. When basalts take the form of a mound, the lower part of the mass often presents a multitude of appendages which

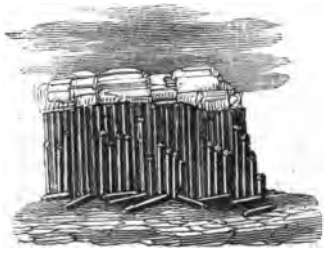


Fig. 34.—Colonnade of Chenavari, near Rochemaure.

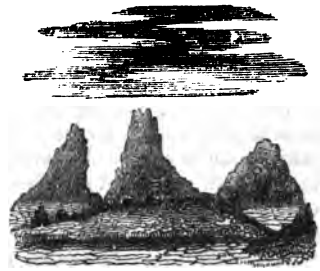


Fig. 35.—Dykes of Chenavari.

penetrate like roots into the subjacent earth; showing that the matter in a liquid state had flowed into the crevices, and moulded itself there. The earth thus in contact with the basaltic mass is often found calcined to a considerable depth, and the vegetable remains which it includes are carbonised. Examples of this are presented upon the cliffs of the plateau of

Mirrabel, in the Vivarais, descending towards St. Jean le Noir, fig. 38.

Fig. 36.

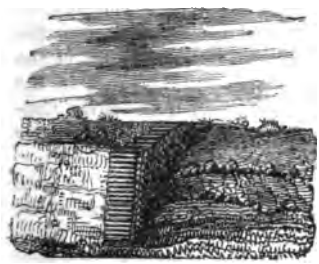


Fig. 38.

96. Grottoes, caves, and tunnels are often found in the midst of these basaltic masses, and in those of trap rocks, which have a close analogy to them. Examples of this may be seen in the Vivarais, on the borders of the Rhine, near Bertrich-Baden, between Trèves and Coblentz, where the columns forming the grotto consist of rounded blocks superposed, resembling a pile of cheeses, from whence the grotto has received the name of Kase Grotte, or Cheese Grotto, fig. 39. But by far the most magnificent of these basaltic grottoes is the celebrated Cave of Fingal, in the Island of Staffa, fig. 37, p. 49.

Fig. 39.—The Kase Grotto of Bertrich-Baden.

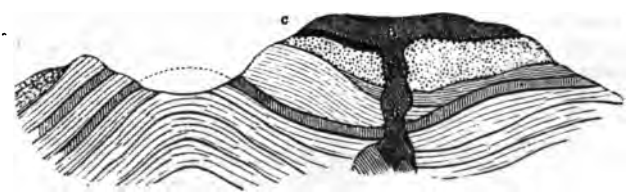
97. Another eruptive product of the terrestrial crust, still more extensive than the basalt, is the trachytic rocks, which form the celebrated Puy-de-dôme, in Auvergne, the Mont D'or, the Cantal,

the Mézenc, and the Mégal, upon the borders of the Velay and the Vivarais. They prevail also on the right bank of the Rhine, and the Siebengebirge. They form immense groups in Hungary and Transylvania, in the Caucasus, in Greece, where their continuation appears in the islands of Milo and Argentiera and extends to the centre of Santorin. They reappear in the Lipari Islands, in the Campania, in the Euganean mountains, in the Azores, in the Canaries, in South America, where the loftiest heights of the Cordilleras are composed of them, in Central Asia, and in many of the islands extending along its coast to Kamschatka.

98. The trachytic formation presents itself not only in isolated mounds, narrow bands, and sheets scattered over the surface of the globe like those of the basalt, but also in vast mountains, generally assembled in large groups, forming the most elevated masses and covered with terrific asperities. Their flanks are torn by precipitous valleys and deep gorges.

99. The matter composing these vast accumulations was evidently ejected from the bowels of the earth by the disruption of the crust, issuing in a state of pasty fusion through the opening thus made in the superjacent stratified rocks, fig. 40.

Fig. 40.



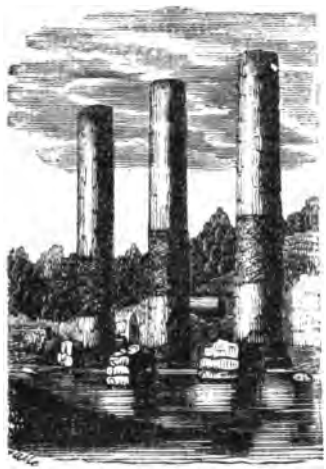


Fig. 52.

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER IV.

100. Elie De Beaumont's explanation of the formation of mountain chains —101. Effects of the earthquake of 1838 in South America.—102. Inference as to the probable effects of the vast earthquakes which produced the great mountain ranges.—103. Dislocations in parallel directions produced parallel chains.—104. Origin of mineral veins explained.—105. Veins are found in groups—generally parallel. —106. Deposition of rock-salt in cavities of Muschelkalk.—107. Natural agencies still manifested are sufficient to explain all geological phenomena.—108. Internal fluidity of the earth—109. Effects of internal heat on the surface.—Why the climates of the higher latitudes at former epochs were similar to those of the tropics at present—explanation of the presence of tropical fossils in polar latitudes.—110. The undulations and disruptions assumed by geologists as physical causes still proceed, though with less energy.—111. Effects of earthquakes—that of Calabria, 1783.—112. Effects in Sicily.—113. Earthquakes at Chili.—114. Earthquake of 1819 in India.—115. Like phenomena recorded in all ages and countries.—116. Similar phenomena traditional—island of Atlantis.—117. Permanency of the sea-level proves the undulations of the land.—118. Undulations of the Swedish peninsula.—119. Similar changes in Greenland, and in the Indian archipelago.—120. General sinking of South America.—121. Singular

example of a submerged forest on the western coast of America.—122. Temple of Jupiter Serapis.—123. Historical researches of Professor Forbes.—124. Tradition of a submerged city under Lough Neagh.—125. Why these undulations of the earth's crust might be expected.—126. Effects of disruption of the crust.—127. Volcanic eruptions of 1808 in the Azores.—128. The Monte Nuovo.

100. THE formation of cracks and fissures in the crust of the globe has been ingeniously explained by M. Elie de Beaumont, as the natural and necessary consequence of the process of superficial cooling taking place upon a globular mass of matter in a state of fusion.

To render intelligible the reasoning and theory of this eminent geologist and naturalist, let us suppose the globe, as we have formerly described it, to have been originally in a state of igneous fusion, and to undergo a gradual superficial cooling, by which a thin solid shell would be formed upon it. The contraction of this shell, taking place from its inner towards its outer surface, would leave a vacant space between the central mass in fusion and the concave interior surface of the solid shell. Supposing also, as we have formerly explained, that after the external surface had fallen below the temperature which maintains water in a state of vapour, the atmospheric vapours, being condensed, had fallen in rain; the external surface of the terrestrial spheroid would then have been covered with an ocean of uniform depth and would consequently have been totally destitute of land.

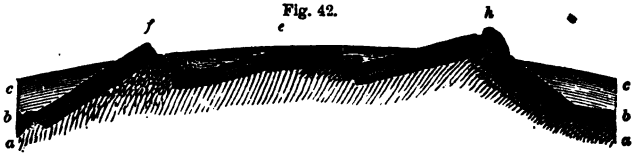
An imaginary section of a part of the terrestrial crust in this state is represented in fig. 41, where *b* is the solid crust, *a* the liquid central mass, *d* the intermediate vacant space, and *c* the ocean of uniform depth covering the entire surface.

Fig. 41.

But the state of equilibrium which would maintain this state of things could not continue. The internal fluid matter would press more or less upon the thin crust surrounding it, which being unequal in its structure, would offer proportionately unequal resistance, and consequently yielding at its weakest points would be dislocated as shown in fig. 42, the fragments being thrown into infinitely various positions. Thus the piece *f* being tilted obliquely, would be raised at one end above the surface of the ocean, depressed at the other. It would, therefore, form a chain of

mountains with a gentle declivity on one side, and abrupt precipices on the other, such as the Pyrenees and the Andes. In other places the two parts fractured would form gentle declivities on both sides,

Fig. 42.



as at *h*. The matter in fusion within the crust forcing its passage upwards in the opening between them would be solidified by the process of cooling on arriving above them. Thus chains of mountains would be formed of moderate declivities on both sides, having igneous rocks at their summits.

In fine, some fragments, such as *e*, would remain nearly level, and would be pushed above the surface, in which case they would form extensive plains of dry land, or might remain below it, in which case they would form the bottom of a shallow sea.

Thus we may understand in its most literal sense the brief description of the formation of the earth in the sacred records: "God divided the land from the water, and saw that it was good."

Such dislocations of the terrestrial crust would not be confined to a single catastrophe, but would from time to time be reproduced. According as, by the continued process of cooling, the solid crust of the earth became thicker and thicker, a vacant space would still be produced between its inner surface and the central fluid matter, and like consequences would from time to time ensue, so that the history of the earth would consist of a series of convulsions by which its crust would from age to age be disrupted, new chains of mountains being formed, and new continents being raised above the waters of the ocean and former ones submerged. Movements of the waters would necessarily attend each such convulsion, compared with which the most violent oceanic commotion with which we are familiar is tranquillity itself.

101. It is related that the earthquake of 1838, which took place at Chili, in South America, although it did not change the level of the continent by more than a few feet, produced effects at the enormous distance of 4000 miles, extending even to the islands of Oceania. The earthquake on the coast of Peru laid in ruins all the towns along the shore. At the moment of the shock, the waters of the ocean, raised with violence, were poured upon the coast, carrying with them an immense mass of sand and shingles,

and transporting vessels of the largest tonnage to a distance of four miles inland.

102. When such effects arise from a change of the surface not exceeding a few feet in elevation, it may be imagined what prodigious deluges must have been produced when the Alps and Pyrenees were raised to their present altitude from the ordinary level of the earth's surface, or when the chain of the Andes was elevated by a dislocation, which must have extended over nearly 3000 miles of the earth's surface.

It cannot then be doubted that the consequence of such convulsions would be universal; and some idea may be formed of the extraordinary ravages which the frightful deluges consequent upon them would occasion upon the surface of the earth, especially at the moment when all levels of land and sea were changed in consequence of the dislocation which caused them, and when a considerable mass of sediment still in a movable state was transported by the torrents of the ocean. It will not be considered extraordinary, that all the terrestrial animals should be at once destroyed by the immediate action of the waters, while the marine animals would suffer equal destruction by the violent transport of the terrestrial matter swept among them.

103. M. Elie de Beaumont has shown that these movements of terrestrial dislocation have never been partial, but that each of them has been produced along lines, having one uniform direction, as may be seen in the case of the Pyrenees, of certain ranges of the Alps, and upon a still greater scale in the case of the Andes and the Himalayas. We shall show more fully hereafter that the parallel lines of mountains have been raised at the same epoch, and that the succession of convulsions by which the ranges of mountains having different directions were produced, can be determined, and their geological dates assigned with more or less precision.

104. The circumstances which have been explained, attending the past history of the earth, have also produced cracks and fissures in its crust, through which the central liquid matter has been forced, and in which it has been solidified, forming veins of mineral matter different altogether from the strata which they intersect. These veins often contain earthy matter, such as carbonate of lime, sulphate of baryta, and quartz, in which case they offer but little interest. They are, however, more frequently filled, either wholly or partially, with metalliferous substances, in which case they acquire great importance. These metalliferous veins are generally found either in the igneous or in the most ancient of the stratified rocks.

105. It is rare that a single vein is met with. Most commonly

great numbers prevail in the same system of strata, and generally take a direction nearly parallel. Fig. 43 shows a transverse section of such a system. The similarity of the mineral matter which fills them demonstrates their common origin. It often happens that one system of such veins is intersected by another, presenting mineral contents totally different from the former. These are called *cross veins*. It is rare that a vein is completely filled with metalliferous matter. Most commonly, these substances form threads, *a*, *b*, *c*, *d*, *e*, *f*, *g*, fig. 44, more or less irregular, included in the middle of the stony crystalline matter which fills the vein. The thickness of the metalliferous thread varies at different parts of the vein; at some points it is considerable, and at others becomes very small, often vanishing altogether.

Fig. 43.

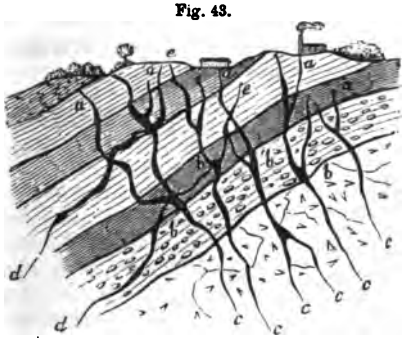
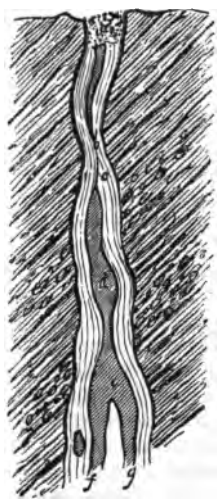


Fig. 44.



106. Numerous cavities are often formed in the midst of stratified rocks, probably by the dissolving action of the subterraneous waters. Such cavities, which are met with in all the sedimentary strata, are generally filled after their formation with new substances totally different from the surrounding rock. It is thus that masses of rock-salt are found in the Muschel-kalk and in the Marnes Irisées, fig. 45.

Similar masses of carbonate of zinc, as formed in the upper part of a stratum of transition limestone, are shown at c c, in fig. 30.

107. Since the memorable revolution effected by Bacon in the conduct of physical inquiries, a maxim has been universally admitted and adopted, in virtue of which, in the formation

of hypotheses for the explanation of natural phenomena, no cause can be admitted, except such as can be shown to have real existence, and which, being admitted, shall appear to be sufficient to produce the phenomena which it is put forward to explain. In accordance with this rule, geologists are therefore required to show

Fig 45.

that the elevated internal temperature of the globe, those upheavings and disruptions of land, those sedimentary deposits from water, those ejections of fluid and pasty matter from clefts and caverns, those abrasions of the solid crust by the corroding action of water, and its modifications by the action of the atmosphere, are severally real agencies still in visible operation, and producing effects similar in kind though different in degree from those ascribed to them in geology, and also that even the difference in degree, which must be admitted to be often very considerable, admits of satisfactory explanation.

Before, therefore, proceeding further in the exposition of the phenomena disclosed by the labours of geologists, we shall here pause for the purpose of showing the reality of the various physical causes to which geologists have ascribed the phenomena. We shall see that like phenomena have been, and still are, developed on the surface of the earth; and that the reasons why these agencies were more energetic at remote epochs than at present are sufficiently obvious.

108. It has been already very fully explained in our Tract on "Terrestrial Heat," that in descending deeper and deeper through the crust of the globe, the temperature continually rises; so that at a depth which forms a very insignificant fraction of the semi-diameter of the globe, the materials which constitute it must have a temperature altogether incompatible with their continuance in the solid state,—a temperature, in short, which is above the point of fusion of the most refractory of these materials.

109. The superficial heat of the earth may be considered, therefore, to result from the combined effects of solar and internal heat. In the present condition of the globe, the effects of the

former are incomparably greater than of the latter; but it may be imagined that at earlier epochs, when the solid crust of the earth was much less thick, the internal heat produced upon the surface a much more powerful effect; so that the climates of all parts of the globe must have been much more elevated than at present. Numerous effects compatible with this reasoning have been discovered by the researches of geologists. Thus, the organic remains of animals and plants found in the sedimentary strata deposited at earlier epochs in the growth of the globe, are such only as could have lived in climates of a much more elevated temperature, than those which now characterise the latitudes in which they are found. Thus, the fauna and the flora (terms adopted by naturalists to express the entire collection of animals and plants existing in any place) prevailing in high latitudes at remote epochs, were such as could exist at present only within the tropics.

110. The alternate upheavings, depressions, disruptions, and dislocations of the crust of the earth assumed by geologists in their explanation of the phenomena are still exhibited, though

Fig. 46.

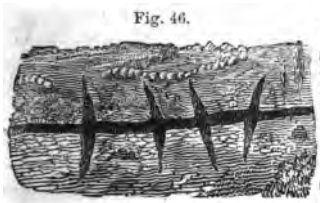
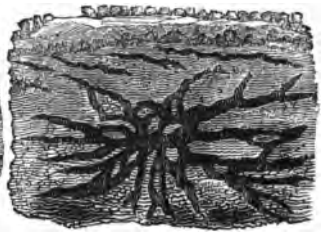


Fig. 47.



on a much smaller scale, in the phenomena attending earthquakes. These effects have been so fully explained in our Tract on "Earthquakes and Volcanoes," that little need be added to what has been there stated. As these phenomena are manifested at present, they are most frequently more or less local, though sometimes their effects are spread over little less than an entire hemisphere. The earthquake which took place in the island of Ischia, on the 2nd of February, 1828, was not felt in the slightest degree either in the neighbouring isles or upon the Continent; while that of New Grenada, which took place on the 17th of June, 1826, exercised its influence over many thousand square miles. The earthquake which commenced in Lisbon in 1755, and which has been fully described in a former Tract, extended in one direction to Lapland, and in the other to Mar-

tinique. It was sensible, also, at right angles to this direction, from Greenland to Africa, where the cities of Morocco, Fez, and Mequinez were destroyed by it. Its effects were manifested in all parts of Europe at the same moment.

111. These convulsions not only destroy entire cities and overturn the most solid edifices, but they are attended with important modifications in the levels of the ground. Those of Calabria, in 1783, supply remarkable examples of them, and are so much the more worthy of attention, as they were circumstantially described by several eminent men who were witnesses of the phenomenon, such as Vicencia, physician of the King of Naples, Grimaldi, Sir W. Hamilton, and by a commission of the Royal Academy of Naples. The whole extent of the country was convulsed, the beds of the rivers were changed, houses were, some raised above the general level, and others at short distances from them sunk below it; edifices of the greatest solidity were cracked in their walls, while certain parts of them were raised above others, and their foundations in many instances forced above the earth; crevices were formed in the ground, some of which measured five or six hundred feet in width; some were straight, some bifurcated; sometimes a single enormous cleft having a certain direction was intersected at right angles by a number of others, fig. 46; others were developed in clefts radiating from a centre, like a broken pane of glass, fig. 47. Some crevices laid open at the moment of a shock, and into which entire buildings had fallen, closed almost immediately again, crushing between their sides all that they had thus engulfed. In some cases the sides of the cleft were separated at the surface, but brought into contact with each other at a certain depth, figs. 48-9. In other cases, the parts disrupted merely sunk below the other without ceasing to be in contact, fig. 50.

Fig. 48.

Fig. 49.

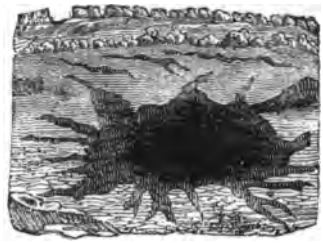
Fig. 50.

In other cases, the force which burst the superior crust was sufficient, not merely to split it into different clefts, but to produce in it a vast cavity, from the edges of which clefts diverged, fig. 51.

In some cases a considerable tract of ground was suddenly engulfed, carrying with it the plantations and buildings which

chanced to be upon it, and leaving nothing but a yawning gulf, with sides nearly vertical, from 300 to 400 feet deep. In some instances an immense quantity of water was collected in the cavities, and formed lakes more or less considerable in magnitude, some of which had no apparent issue, while the water from others flowed in enormous torrents. In other cases the contrary effects were manifested, rivers and lakes suddenly disappearing as if they had sunk into the bowels of the earth.

Fig. 51.



112. While the principal of these earthquakes upon the Italian peninsula was limited to the tract between Oppida and Soriano, the phenomena were propagated under the straits of Messina to that city, more than half of which, with twenty-nine surrounding towns and villages, was swallowed up. The bottom of the sea sunk, the shores were torn by clefts, and all the ground along the harbour of Messina was inclined towards the sea, sinking suddenly to the depth of some feet. The entire promontory by which the entrance to the harbour was formed, was swallowed up in an instant.

113. The earthquakes which took place on the coast of Chili in 1822—35—37, produced effects not less remarkable. Different parts of the coast from Valdivia to Valparaiso, an extent of more than 200 leagues, was manifestly raised above the water, as well as several adjacent islands extending to that of Juan Fernandez. The bottom of the sea, to a considerable distance, was similarly affected. Upon the coasts, rocks formerly covered with water, were raised eight or ten feet above the level of the sea, covered with the shells attached to them. Rivers, which emptied themselves at different parts of the coast, and which were navigable to vessels of small tonnage, became fordable. At sea, well known anchorages were diminished in depth; and various parts, where vessels formerly passed safely, were now complete shoals, inaccessible to vessels except those of the lightest draught.

114. Similar effects were manifested in India in 1819. A hill, 60 miles long, and 18 wide, extending from S.E. to N.W., was raised in the middle of a flat country, barring the course of the Indus. Further south, and in a parallel direction, the ground was sunk and with it the town and fort of Sindré, which remained, however, standing, though half submerged. The eastern embouchure

of the river became deeper at several places, and different parts of its bed, formerly fordable, ceased to be so.

115. In the records of all ages and countries, effects of the same kind are recorded. Large crevices in the earth have been formed, deep gulfs opened, into which cities, and even whole countries, have sometimes been swallowed up. From these openings, mephitic vapours, water in enormous quantities, sometimes cold, sometimes warm, have been ejected, and, occasionally, even flame has issued. Plains have been suddenly transformed into mountains, shoals produced in the deepest seas, mountains cracked and overturned, and mountainous tracts, many hundred miles in extent, suddenly levelled or replaced by deep lakes; rivers, turned from their beds, have discharged their waters into cavities thus formed; lakes, breaking through their banks, have been emptied, and their bottoms left dry, or have been turned through subterraneous openings suddenly formed beneath them. On the contrary, in some cases numerous springs, natural artesian wells, have been formed, supplying waters which suddenly issued from crevices of the rock or from tunnels. Thermal springs have been suddenly rendered cold, or altogether dried up, while others, on the contrary, have been produced where none existed.

All these, and many other phenomena, indicate the existence of internal convulsions, by which the matter subjacent to the crust of the earth is driven upwards through its crevices.

116. Independently of the phenomena of this class which are authentically recorded in history, many others are subjects of tradition. Thus, Pliny relates a tradition that Sicily had been separated from Italy, Cyprus from Syria, and Eubœa from Bœotia, by earthquakes. According to another classical tradition, a great island called Atlantis existed in ancient times west of the Straits of Gibraltar, having a numerous population. Its princes invaded Africa and Europe, but were defeated by the Athenians and their allies. Its inhabitants afterwards became wicked and impious, and the island was visited with the vengeance of the Gods, and swallowed up by the ocean in a single day and night. This legend is given by Plato, and is said to have been related to Solon by the Egyptian priests. According to all the analogies supplied by the phenomena described above, there is nothing impossible, or even improbable, in that part of this legend which refers to an island being engulfed by the ocean.

117. The cases in which the dry land has been invaded by the sea, or the bed of the sea left dry by the retirement of the waters, has been popularly, and even by the scientific of former days, ascribed to the change in the level of the waters of the ocean, their elevation producing inundations, and their fall leaving

tracts, formerly covered, dry. Considering the solid and apparently permanent character of the land on the one hand, and the extreme mobility of water on the other, such a conclusion was natural, and almost inevitable, until clear evidence of the contrary was obtained. It has, however, been proved that the very reverse has been the case of such phenomena, the mobility appertaining to the land, and the permanence to the sea. It has been shown, by observations made upon the level of the ocean, that it has not suffered any general change within historic times; but, on the contrary, that the cases in which the land has been inundated by the ocean must be ascribed to the sinking of the land, and those in which the waters have deserted their bed to the rising of the bottom of the sea.

118. These changes in the level of the crust of the earth have been in some cases sudden, as when they are produced by earthquakes, but in others they have been so gradual that they could only be ascertained by observation extending over long intervals of time. It had been long observed in different parts of Sweden, that the level of the surrounding ocean was subject to an apparent but slow and gradual change, in some places rising, in others falling. The Academy of Upsal, in 1731, commenced a series of observations with a view of determining the fact whether this apparent change of the ocean were real, or whether it were not caused by an actual change in level of the land. Marks were accordingly cut upon the faces of rocks at the level of the sea, and at the end of some years these marks were several inches above that level, from whence it was in the first instance inferred that the Baltic had suffered a depression of its level, so as to leave more or less of the bottom dry. These observations, however, being continued and multiplied, it was soon rendered apparent that, while the level of the Baltic remained unchanged, the phenomena were produced by actual changes in the level of the land. It was found that the apparent depression of the level of the ocean was different in different places, and that in some places, on the contrary, it appeared to have been even raised. Thus, while at certain points the apparent depression amounted to several inches, in others it did not exceed a fraction of an inch; at some places, such as the coast near Christianstad, the level of the sea appeared to be elevated. The conclusion deduced from all these observations was, that the apparent change of level of the sea was produced by a slow and gradual upheaving of the land in some places, and a sinking in others; that in Finland, and in a great part of Sweden, the surface was gradually raised without any perceptible shock, while in the southern parts of the peninsula a corresponding depression was produced.

119. Similar swellings and depressions of the land have been manifested elsewhere. Thus, for four centuries, the western coast of Greenland has been continually sinking through an extent of 600 miles north and south. Ancient buildings, as well upon the low islands of the coast as upon the mainland, have been gradually submerged, and the removal to considerable distances inland of various establishments which formerly existed upon the coast, has been rendered necessary. Similar sinkings of the surface have been manifested in certain islands of the Southern Ocean, especially in the Indian Archipelago.

120. It would even appear, from a comparison of the observations of Messrs. Boussingault and Humboldt, separated by an interval of thirty years, that the whole continent of South America is gradually sinking, and, if this process be continued, at some distant epoch it may even be submerged. The observations referred to show that the altitudes of the Andes at the epoch of the observations of Boussingault were less than those given by the anterior observations of Humboldt; and these results are confirmed by the fact that the snow-line in this range of mountains has, in the interval referred to, apparently risen.

121. An interesting modern example of the subsidence of a considerable tract of country, clothed with forests, the trees remaining erect, although submerged beneath a river which still flows over them, is described by a late American writer, and will serve to illustrate these remarks. The whole district, from the Rocky Mountains on the east, and the Pacific Ocean on the west, and from Queen Charlotte's Island on the north, to California on the south, presents one vast tract of volcanic formation. Basalt—both columnar, and in amorphous masses, veins, and dykes—everywhere occurs, and craters of extinct volcanoes are still visible. Elevations and dislocations of the strata have taken place on an immense scale; and successive beds of basalt, amygdaloidal trap, and breccia, prove the alternation of igneous action and periods of repose. Within a few miles of the falls of the river Columbia, and extending upwards of twenty miles, trees are seen standing in their natural position, in a depth of water from 20 to 30 feet. The trees reach to high or fresh-water mark, which is 15 feet above the lowest level of the tide; but they do not project beyond the freshet rise, above which their tops are decayed and gone. In many places the trees are so numerous, that "we had to pick our way with the canoe, as through a forest. The water of the river was so clear, that the position of the trees could be distinctly seen, down to their spreading roots, and they are standing as in their natural state, before the country had become

submerged. Their undisturbed position proves that the subsidence must have taken place in a tranquil manner." *

122. Another most interesting and remarkable example of the alternate elevation and depression of the surface of the earth, manifested within historic times, is presented in the case of the ground upon which the temple of Jupiter Serapis stands, at Pozzuoli, near Naples. These ruins, standing on the northern shore of the Bay of Baiæ, at a short distance from the Solfatara, consist of the remains of a large building of quadrangular form, 70 feet in diameter, the roof of which was originally supported by 46 columns, 24 of which were granite, and 22 marble, each column consisting of a single stone. Many of these pillars are broken, and their fragments strewn about the pavement, but three of them still remain standing (fig. 52). Their base is near the level of the sea. The surface of the columns, the tallest of which is 42 feet in height, is smooth up to an elevation of 12 feet from the pedestal, where a band of perforations 9 feet wide commences, made by a species of mussel, called the *Modiola lithophaga*, which could only have lived in sea-water. Above this band, at the height of 21 feet from the pedestal, these cavities are discontinued, and the remainder of the pillars are smooth, like the lower part. The cavities, many of which still contain shells, sand, and microscopic shields, are of elongated elliptical shapes, and so numerous and deep as to prove that the pillars must have been submerged in sea-water to a height more or less above the limit of these borings, for a long period of time. The lower part of the columns, which are not similarly affected, must have been protected, while they were submerged, from the depredations of these boring mussels by surrounding accumulations of rubbish and tufa, while the upper parts projected above the water, and were consequently beyond the reach of these animals.

The platform of the temple is now about one foot below high-water mark, and the sea, which is only 40 yards distant, penetrates the intervening soil. The upper part of the band of perforation is at least 23 feet above the level of the sea.

It appears from all this, that the ground on which the temple stands must have changed its level more than once, being alternately heaved upwards and downwards. It is clear that when the temple was built, the ground of its foundation must not only have been high and dry, but remote from the shores of the bay, and at some subsequent period must have sunk gradually, and so

* Journal of an Exploring Tour beyond the Rocky Mountains, by the Rev. Samuel Parker, A.M. New York, 1838.

tranquilly as not to overturn the columns, to a depth above the band of perforation, and at a still more recent period must have again been raised to its present level.

123. It results from the researches of Professor Forbes upon this subject, that historical evidence is extant illustrating the respective dates of these changes of level. From inscriptions recording the embellishment of the temple by Septimius Severus (A.D. 193—211), and Marcus Aurelius (A.D. 161—180), it appears that the building was still entire, and occupied its present position at the close of the second and commencement of the third century; that in A.D. 1198, the eruption of the volcanic lake of Solfatara took place, attended with earthquakes, and a general subsidence of the coast ensued, which caused the temple to sink to a depth which submerged its columns in water to a height above the band of perforations. In this state it appears to have continued until the commencement of the sixteenth century; for the flat district called La Starza, in which the building stands, is described by contemporary observers as being covered by the sea in 1530. Eight years later, frequent and violent earthquakes prevailed along all that part of the Neapolitan coast; and on the 29th of September in that year, the volcanic eruptions burst forth which threw up the Monte Nuovo already described. During this catastrophe the coast on the north of the Bay of Baiæ was permanently raised 20 feet, forming a tract 600 feet in breadth, and including the area in which—

> "Those lonely columns stand sublime,
> Flinging their shadows from on high,
> Like dials, which the wizard Time
> Had raised to count his ages by!"—MOORE.

These were accordingly left above the water, several of the columns still retaining their original position. They seem to have been wholly neglected by antiquaries till 1750, when the shrubs and weeds with which they were overgrown and concealed were removed, and the earth accumulated in the court of the temple cleared away. For the last thirty or forty years a slow subsidence of the coast appears to have been going on, and the floor of the temple is often submerged.*

124. We are not informed whether the Irish tradition, reproduced by Moore so beautifully in the following lines, has been verified by any scientific observers; but, if so, it would seem as

* See a paper by Professor Forbes on the subject in Brewster's "Journal of Science," vol. i. second series; and also a letter quoted by Dr. Mantell, and addressed to him by M. Hullmandel, "Wonders of Geology," vol. i. p. 458.

though Lough Neagh were the result of a post-Adamite sinking of the ground.

"On Lough Neagh's banks as the fisherman strays,
When the clear cold eve's declining,
He sees the round towers of other days
In the wave beneath him shining!

Thus shall memory, often, in dreams sublime,
Catch a glimpse of the days that are over;
Thus, sighing, look through the waves of time
For the long faded glories they cover!"—MOORE.

125. It appears, then, that the crust of the earth, instead of being endowed with that character of stability and immobility popularly ascribed to it, is subject to incessant as well as occasional upheavings and depressions. It may indeed be regarded as in a certain degree elastic, yielding to the undulations, whether slow and gradual, or sudden and more violent, of the agencies within it.

Such phenomena, however, will cease to astonish when we reflect what an enormous disproportion exists between the thickness of the solid crust of the globe, and the mass of matter in a state of igneous fusion which it encloses; the crust being relatively thinner than a piece of card-board attached to the rind of an orange, it cannot be matter of surprise that it should be subject to more or less derangement of form, and even occasional disruption, by the action of the fluid matter within it. That such changes and such disruptions and their consequences should be much more considerable at earlier than at more recent epochs, is also a natural consequence of the growth of the crust of the globe by the process of cooling. The earlier the epoch the thinner that crust must have been, and the less its resistance to internal force. Forces which would now fail to produce any sensible effect upon its form, would at those earlier epochs have been sufficient to disrupt it. That such effects have been actually produced at various geological epochs is proved by the most incontrovertible evidence presented by the crust of the globe itself, as will presently be more fully explained. Volcanic phenomena are closely connected with those of earthquakes, and, like them, supply analogies by which various geological phenomena are explained.

126. When the crust of the earth is disrupted in the manner explained above, openings are made in it which supply communication between its internal fluid nucleus and its external surface, and through these openings matter of various forms is often ejected with vast force. The matter thus ejected consists sometimes of the disrupted and broken parts of the crust itself, which are projected upwards, vertically or obliquely as the case may be,

and often scattered over the surrounding country to vast distances. Sometimes the matter thus thrown up is in a state of pasty fusion, and is incandescent, scoriaceous, and pumiceous. In this semi-fluid state it is projected sometimes to a distance, and sometimes it flows in streams along the slopes of declivities, or collects in a sheet or layer of more or less thickness round the crater from which it is ejected.

127. These volcanic phenomena have been already, in part, explained in our Tract on Earthquakes and Volcanoes, but their connection with the condition and history of the crust of the earth is so close, and the aids they afford for the explanation of geological phenomena so important, that it will be necessary here further to enlarge upon them.

In the month of May, 1808, the ground in the island of San Jorge, one of the Azores, in the midst of an open plain and cultivated fields, was suddenly upheaved, after which it cracked at several places with a terrific noise. A vast cavity or crater was formed in the middle of it, having an area of nearly thirty acres, and surrounded within the distance of three miles by from twelve to fifteen smaller craters. An enormous quantity of scoriaceous and pumiceous matter was projected from it which covered the surrounding ground to the depth of five feet for an extent of twelve miles in length by three in breadth. Streams of molten matter issued from it, which continued to flow for more than three weeks from the principal crater to the sea.

128. The Monte Nuovo, which was formed upon the Neapolitan coast in the Bay of Baiæ in 1538, presents an example of like phenomena. A violent earthquake had prevailed for two years, which, on the 27th and 28th of September, 1538, suddenly increased so as to be attended with incessant movement of the ground day and night. The plain extending between the Lake of Averno (the ancient Avernus), the Monte Barbaro and the sea was then suddenly upheaved, and various crevices were formed in it; the ground, rising still more, assumed the form of a mountain. During the succeeding night, the summit of this mountain opened with prodigious noise, and vomited great masses of flame, accompanied by pumice stones and ashes. The eruption continued for seven days, the matter ejected filling up the Lucrine Lake. Since this eruption the most perfect tranquillity has continued at this place.

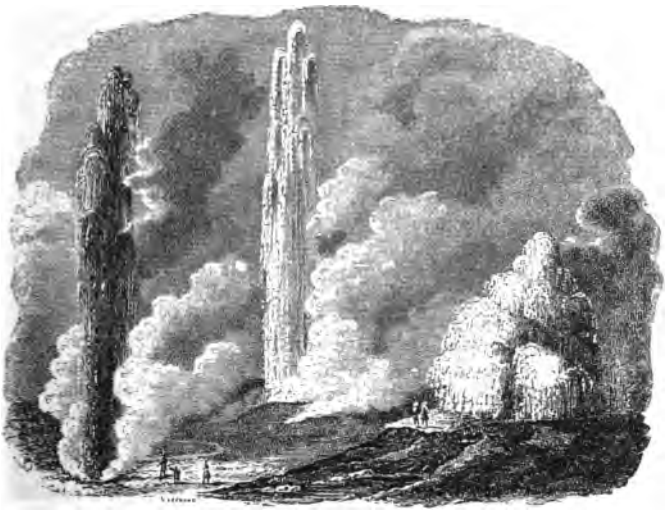


Fig. 71.—THE GEYSERS, ICELAND.

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER V.

129. Volcanoes of the Andes—Pichiucha, Cotopaxi, and Tunguragua.—130. Mexican volcanoes—Orizaba, Popocatapetl, Jorullo, and Colima. 131. Singular circumstances attending the elevation of Jorullo.—132. Ancient state of Vesuvius, according to Strabo—Eruption of 76 A.D.—Destruction of Herculaneum and Pompeii.—133. Volcano of Kirauea in Owhyhee—Mr. Ellis's account of it.—134. Visit of Mr. Stewart and Lord Byron to it in 1825—Mr. Stewart's account of it.—135. Illustrations of the ejection of lava through the strata.—136. Effect of obstruction—formation of lateral craters.—137. Submarine eruptions—Formation of volcanic islands.—138. Volcanic islands off Santorin, in the Grecian Archipelago.—139. Phenomena attending the formation of such islands.—140. Craters of elevation.—141. Stratification around these craters—Island of Palma.—142. Formation of islands not necessarily preceded by eruptions.—143. Mount Etna.—144. Historical accounts of its eruptions.—145. Eruption of 1832.—146. The

Val del Bove.—147. Section and plan of Etna.—148. Volcanic lakes.—149. Crescent form of volcanic islands.—150. Craters of elevation, temporary and permanent.—151. Barren island in the Bay of Bengal.—152. Traditional volcanic origin of Santorin.

129. THE famous volcano of Jorullo in the Anahuac mountains in Mexico had its origin in similar phenomena. The elevated plateau which forms the province of Quito, in South America, has been the theatre of extraordinary volcanic phenomena. Beneath it is a focus of volcanic energy, the channels of which communicate with the atmosphere by the craters of the great volcanoes of Pichincha, Cotopaxi, and Tunguragua, part of the chain of the Andes. These, by their groupings as well as by their lofty elevation and grand outlines, present the most sublime and picturesque aspect which is anywhere concentrated within so small a space in a volcanic landscape. The extremities of the chain are connected by subterranean communications; and this fact, which experience has made known to us in numerous instances, reminds us of the old and just statement of Seneca, that the crater is only the issue of more deeply-seated volcanic forces.

130. The Mexican volcanoes of Orizaba, Popocatapetl, Jorullo, and Colima also appear to be connected with each other, being placed in the direction of a line running transverse to the former, and passing east and west from sea to sea.

131. As was first observed by Humboldt, these mountains are all situated between north latitude 18° 59′ and 19° 12′. In an

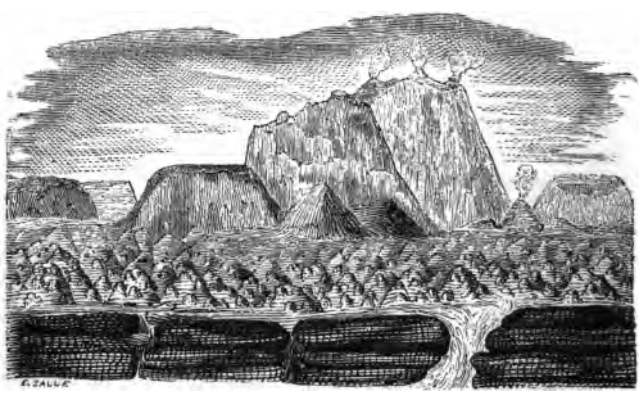


Fig. 53.—Volcano of Jorullo, Mexico.

exact line of direction with the other volcanoes, and over the same transverse fissure, Jorullo was suddenly elevated on the

29th of September, 1759. The circumstances attending the production of this volcano are so remarkable, that we shall here notice them in some detail.*

An extensive plain, called the Malpays, was covered by rich fields of cotton, sugar-cane, and indigo, irrigated by streams, and bounded by basaltic mountains, the nearest active volcano being at the distance of eighty miles. This district, situated at an elevation of about 2600 feet above the level of the sea, was celebrated for its beauty and extreme fertility. In June, 1759, alarming subterranean sounds were heard, and these were accompanied by frequent earthquakes, which were succeeded by others for several weeks, to the great consternation of the neighbouring inhabitants. In September tranquillity appeared to be re-established, when, in the night of the 28th, the subterranean noise was again heard, and part of the plain of Malpays, from three to four miles in diameter, rose up like a mass of viscid fluid, in the shape of a bladder or dome, to a height of nearly 1700 feet; flames issued forth, fragments of red-hot stones were thrown to prodigious heights, and, through a thick cloud of ashes, illumined by volcanic fire, the softened surface of the earth was seen to swell up like an agitated sea. A huge cone, above 500 feet high, with five smaller conical mounds, suddenly appeared, and thousands of lesser cones (called by the natives *hornitos*, or ovens,) issued forth from the upraised plain. These consisted of clay intermingled with decomposed basalt, each cone being a *fumarolle*, or gaseous vent, from which issued thick vapour. The central cone of Jorullo is still burning, and on one side has thrown up an immense quantity of scoriaceous and basaltic lavas, containing fragments of primitive rocks. Two streams, of the temperature of 186° of Fahrenheit, have since burst through the argillaceous vault of the hornitos, and now flow into the neighbouring plains. For many years after the first eruption, the plains of Jorullo were uninhabitable from the intense heat that prevailed.†

132. It appears that the cone from which Vesuvius takes its present character has been the result of similar effects.

In the description of the mountain given by Strabo, no mention whatever is made of the cone which now forms its most remarkable feature. The slopes of the mountain, says Strabo, were regions of the greatest fertility; its summit was truncated, entirely sterile, and had a burnt aspect, displaying cavities full of crevices and calcined stones, from which it must be conjectured that they had been formerly volcanic craters. It seems, therefore, that the cone to which the name of Vesuvius now more

* Cosmos, vol. i. p. 229. Trans.
† Mantell, p. 837.

properly belongs, and of which all the products differ altogether from the rocks of the semicircle called the *Somma* which existed in ancient times, was not formed until a much more recent period, and probably dates from the famous eruption of the year 76 A.D., which was signalised by the loss of Pliny. It was then, probably,

Fig. 54.—Vesuvius as now formed.

Fig. 55.—Vesuvius in the time of Strabo.

that a permanent communication was opened between the crater and the internal parts of the earth. This catastrophe appears to have produced but little lava, although it was attended with violent effects on the surrounding country, throwing a great part of the mountain into the sea, and burying Herculaneum and Pompeii, not, as is vulgarly supposed, under molten matter ejected from the crater, but under avalanches of pumiceous substance, which existed previously upon the slopes of the mountain.

133. Of all existing volcanoes, that of Kirauea, in Hawaii, one of the Sandwich Islands, better known under the popular name of Owhyhee, and noted as the theatre of the murder of Captain Cook, exhibits volcanic phenomena under their most sublime and imposing aspect. The island of Hawaii, which is about seventy miles long, and covers an area of 4000 square miles, is a complete mass of volcanic matter, perforated by innumerable craters. It is, in fact, a hollow cone, rising to an altitude of 16000 feet, having numerous vents over a vast incandescent mass, which doubtless extends beneath the bed of the ocean, the island forming a pyramidal funnel from the fluid nucleus beneath to the atmosphere. The following graphic account of a visit to the crater, by Mr. Ellis, affords a striking picture of the splendid, but awful, spectacle which this volcano presents.

"After travelling over extensive plains and climbing rugged steeps, all bearing testimony of igneous origin, the crater of Kirauea suddenly burst upon our view. We found ourselves upon the edge of a steep precipice, with a vast plain before us fifteen or sixteen miles in circumference, and sunk from two to four hundred feet below its original level. The surface of this plain was uneven, and strewed over with large stones and volcanic rocks; and in the centre of it was the great crater, at the distance of a mile and a half from the precipice on which we were standing. We proceeded to the northern end of the ridge, where, the sides being less steep, a descent to the plain below seemed practicable;

but it required the greatest caution, as the stones and fragments of rocks frequently gave way under our feet, and rolled down from above. The steep which we had descended was formed of volcanic matter, consisting apparently of light red and grey vesicular lava, lying in horizontal beds, varying in thickness from one to forty feet. In a few places the different masses were rent in perpendicular and oblique directions, from top to bottom, either by earthquakes, or by other violent convulsions of the ground. After walking some distance over the plain, which in several places sounded hollow beneath our feet, we came to the edge of the great crater. Before us yawned an immense gulf in the form of a crescent, about two miles in length from the north-east to south-west, one mile in width, and 800 feet deep. The bottom was covered with lava, and the south-west and northern parts were one vast flood of burning matter. Fifty-one conical islands of varied form and size, containing as many craters, rose either round the edge or from the surface of the burning lake. Twenty-two constantly emitted either columns of grey smoke or pyramids of brilliant flame, and at the same time vomited from their ignited mouths streams of lava, which rolled in blazing torrents down their black indented sides into the boiling mass below. The existence of these conical craters led us to conclude that the boiling cauldron of lava did not form the focus of the volcano, but that this liquid mass was comparatively shallow, and the basin which contained it separated by a stratum of solid matter from the great volcanic abyss, which constantly poured out its melted contents through these numerous craters into this upper reservoir. We were further inclined to this opinion from the vast columns of vapour continually ascending from the chasms in the vicinity of the sulphur banks and pools of water, for they must have been produced by other fire than that which caused the ebullition in the lava at the bottom of the great crater; and also by noticing a number of small vents in vigorous action high up the sides of the great gulf, and apparently quite detached from it. The streams of lava which they emitted rolled down into the lake, and mingled with the melted mass, which, though thrown up by different apertures, had perhaps been originally fused in one vast furnace. The sides of the gulf before us, although composed of different beds of ancient lava, were perpendicular for about 400 feet, and rose from a wide horizontal ledge of solid black lava, of irregular width but extending completely round. Beneath this ledge the sides sloped gradually towards the burning lake, which was, as nearly as we could judge, three or four hundred feet lower. It was evident that the large crater had been recently filled with liquid lava up to this ledge, and had, by some subterranean

channel, emptied itself into the sea, or upon the low land on the shore; and in all probability this evacuation had caused the inundation of the Kapapala coast, which took place, as we afterwards learned, about three weeks prior to our visit. The grey, and in some places apparently calcined sides of the great crater before us—the fissures which intersected the surface of the plain on which we were standing—the long banks of sulphur on the opposite sides of the abyss—the vigorous action of the numerous small craters on its borders—the dense columns of vapour and smoke that rose out of it, at the north and south ends of the plain, together with the ridge of steep rocks by which it was surrounded, rising 300 or 400 feet in perpendicular height—presented an immense volcanic panorama, the effect of which was greatly augmented by the constant roaring of the vast furnaces below." *

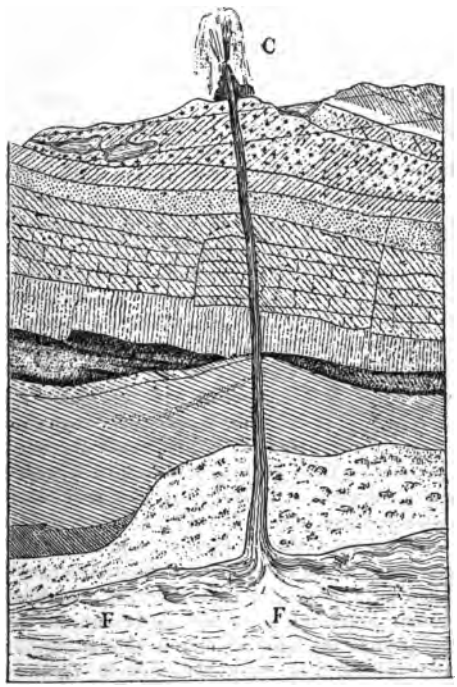
134. This volcano was also visited in 1825 by Mr. Stewart, accompanied by Lord Byron and a party from the "Blonde" frigate, who descended to the bottom of the crater. Mr. Stewart has left the following description of it:—"The general aspect of the crater," observes he, "may be compared to that which the Otsego Lake would present, if the ice with which it is covered in winter were suddenly broken up by a heavy storm, and as suddenly frozen again, while large slabs and blocks were still toppling, and dashing and heaping against each other, with the motion of the waves. At midnight the volcano suddenly began roaring, and labouring with redoubled activity, and the confusion of noises was prodigiously great. The sounds were not fixed or confined to one place, but rolled from one end of the crater to the other; sometimes seeming to be immediately under us, when a sensible tremor of the ground on which we lay took place; and then again rushing on to the farthest end with incalculable velocity. Almost at the same instant a dense column of heavy black smoke was seen rising from the crater directly in front, the subterranean struggle ceased, and immediately after flames burst from a large cone, near which we had been in the morning, and which then appeared to have been long inactive. Red-hot stones, cinders, and ashes, were also propelled to a great height with immense violence; and shortly after, the molten lava came boiling up, and flowed down the sides of the cone and over the surrounding scoriæ, in most beautiful curved streams, glittering with a brilliancy quite indescribable. At the same time, a whole lake of fire opened in a more distant part. This could not have been less than two miles in circumference, and its aspect was more horribly

* Ellis's Polynesian Researches, vol. iv.

sublime than anything I ever imagined to exist, even in the ideal visions of unearthly things. Its surface had all the agitation of the ocean; billow after billow tossed its monstrous bosom into the air, and occasionally those from different directions burst with such violence, as in the concussion to dash the fiery spray forty or fifty feet high. It was at once the most splendid and fearful of spectacles."

135. The manner in which the liquefied matter is driven upwards through the superjacent crust of the earth, and ejected from the crater is illustrated in fig. 56, where F F represents

Fig. 56.



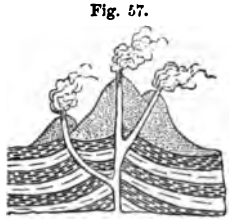
the fluid nucleus of the globe, and F C the passage along which the fluid matter has burst its way through the successive strata to the crater from which it issues.

136. It sometimes happens that the passage, through which it is thus forced in the first instance becomes obstructed, so

that the escape of the lava through it is intercepted. In such cases the pressure of the fluid matter acting against the walls of the cleft, or channel, breaks through them at one or more points of least resistance, and new issues are formed on another side of the original crater. These lateral craters may also be produced, even though the central crater is still in activity (fig. 57).

137. Volcanic eruptions are not confined to the land, but are often produced in the bed of the ocean. In such cases islands often rise suddenly out of the bottom of the deep. Thus, in 1831, the island of Julia arose in the Mediterranean, about 30 miles to the south-west of Sicily. Bogoslaw appeared in like manner, in 1814, in the Aleutinian Archipelago; Sabrina and another among the Azores, in 1811; besides various others around Iceland, in the Indian Archipelago, the Philippines, the Moluccas, and off the coast of Kamtschatka. One of the most remarkable examples of these was presented in the case of the island which rose above the waters, in 1796, at 30 miles from the northern point of Unalaska, one of the Aleutinian islands. A column of smoke was first seen to rise out of the sea. This was followed by the appearance of a black point at the surface of the water, from the summit of which blades of flame and incandescent matter were launched with violence. These phenomena continued for several months, during which the island increased greatly in magnitude and height. Afterwards, smoke alone issued from it, which, after continuing four years, ceased. The island nevertheless, still continued to increase in magnitude and height, without manifesting volcanic phenomena. In 1806, it had so augmented that it formed a cone, which could be perceived from Unalaska, upon which were formed four other smaller cones in the north-west side.

Fig. 57.



138. Some remarkable examples of submarine eruptions have been presented from the most remote times, in the Mediterranean and the Levant. According to ancient historians, the bay included between the islands of Santorin and Theresia (fig. 58), in the Grecian Archipelago, has been the special theatre of these phenomena. The island of Santorin is a half-moon-shaped tract of land, evidently of volcanic origin, and the islands of Theresia and Aspronisi, extending between the horns of the crescent, enclose the bay. Within this enclosure, the island of Hiera rose above the water in 186 B.C., and round it, and close to its coast several islets appeared in 19 A.D., 726 A.D., and 1427 A.D. In

1573 A.D., appeared the large island called Micra Kamini, and in 1707, the still larger one, Nea Kamini. The latter underwent a gradual increase of magnitude during several succeeding years.

Fig. 58.

No volcanic crater was formed upon these islands, which appear to cover the orifices in the subjacent crust through which the liquid matter which forced them up acted.

139. These submarine volcanic phenomena are generally preceded by incandescent matter thrown above the waters, by scoriaceous and pumiceous matter appearing on the surface, by burning rocks which appear in the midst of vaporous waves, and by the ebullition of the sea, the temperature of which then becomes very elevated. All these effects were manifested in modern times in the appearance of the islands of Julia, Sabrina, and others, and the more ancient phenomena are similarly described in historic narratives.

The circumstances attending them, however, are not always identical. Sometimes no solid rock is raised above the water. Thus, for example, at Kamtschatka, in 1737, jets of vapour only were thrown up. Great ebullitions of the sea took place, and pumiceous matter flowed on the surface. On the subsidence of the eruptions, it was found that chains of submarine mountains had been formed where previously there was a depth of 100 fathoms. In other cases there are not even jets of vapour, and the phenomenon is manifested only by the increased temperature

of the waters, and by the sudden elevation of the matter which existed at the bottom of the sea. This took place in 1820 at the island of Banda in the Moluccas, where the bay, which previously had a depth of 50 fathoms, was elevated by the tranquil upheaving of compact basaltic matter which previously existed there, and which formed a promontory composed of large blocks piled one upon the other, without any accessory phenomena except the increased temperature of the waters.

It has been ascertained also that violent submarine eruptions are often followed by slow and gradual upheavings of the bottom of the sea. This effect was manifested in the case of the island near Unalaska, and also in those produced near Santorin. It may be added also, that the islands thus produced are not always permanent; many of them disappear after intervals of more or less duration, being either swept away by the water or sinking into abysses formed under them.

140. Volcanic craters, which result from the upheaving of the crust of the earth in places where no volcano previously existed, are distinguished by the name of CRATERS OF ELEVATION, from those craters which break out at different points in existing volcanoes. In like manner, the conical mounds similarly formed are called cones of elevation. Craters of elevation are distinguishable even in places where no record or tradition of eruption exists, by the arrangement of the strata elevated, which is altogether dissimilar from what is found elsewhere. These strata are always inclined in all directions round the axis of the cone, as shown in fig. 59, presenting their edges abruptly towards the centre of the cavity. The Monte Nuovo, already mentioned, presents an example of this upon a small scale. The same formation is presented in the case of the semicircular Somma of Vesuvius.

141. Another characteristic, not less important, and especially useful for geological purposes in cases where the matter elevated is not stratified, is supplied in all great craters of elevation by the crevasses which extend from the borders of the crater to the external base of the mountain, and which are presented in so remarkable a manner in the Canaries, where they are called Barancos. These radiating crevasses are admirably shown upon the plan of the island of Palma, one of the Canaries, drawn by M. de Buch.

Fig. 59.

One of these Barancos, much deeper than the others, extends from the foot of the mountain, at a place called Tazacorte, to the base of the crater, as shown in the plan, and which is rendered still more apparent in the perspective view shown in fig. 61.

ISLAND OF PALMA.

The volcanic islands which have arisen out of the ocean have assumed forms, all of which are analogous to those here described.

Fig. 60.—Plan of the island of Palma, one of the Canaries.

Thus for example, the island of Sabrina, at the moment of its

Fig. 61.—Perspective view of Palma.

appearance, took the form of a crater which had an opening to

the south, and which was terminated by crevasses from which boiling-water issued.

142. Although the crater-formed cavities which are so frequently observed at various parts of the surface of the earth have been in many cases preceded by volcanic eruptions, they are not invariably to be ascribed to that cause, and indeed in many cases there is abundant evidence that no such eruption could have taken place at the moment of their formation. We have already explained how the upheaving of the crust of the earth, produced by an earthquake shock, can produce not only radiating clefts, as in fig. 47, but also an open cavity, as in fig. 51, the edges of which are surrounded by divergent clefts.

143. Mount Etna, the most remarkable of European volcanoes, situated on the island of Sicily, and composed entirely of erupted mineral substances, rises to a height above the level of the Mediterranean of nearly eleven thousand feet. The circumference of its base is more than a hundred and eighty miles, and on a clear day it may be distinctly seen from any elevated point of the island of Malta, a distance of a hundred and fifty miles. Compared with this volcano, Vesuvius is insignificant. While the streams of lava from the latter never exceed seven miles in length, those of Etna very often are from fifteen to thirty miles, being five miles in breadth, and from fifty to a hundred feet in thickness. The surface of Etna presents three distinct regions. Around the base for an extent of twelve miles, the country is richly cultivated, and abounds in vineyards and pastures, and is the site of many towns, monasteries, and villages. The middle or temperate zone above is covered with forests of oak and chestnut, and a luxuriant vegetation reaches to within a mile of the summit. Above this all is sterility and desolation, and the highest point of the mountain is covered with eternal snow. The crater is about a quarter of a mile in height, and three-quarters of a mile in circumference, and is situated in the centre of a gently inclined plain, three miles in diameter. From the crater a column of vapour constantly issues, emanating from the mass of incandescent mineral matter which fills up the interior, and may be seen, in a state of ebullition, in the fumarolles in some of the lateral crevices, of which there are generally several accessible.

144. Etna is recorded as having been in a state of activity before the Trojan war; and ever since, at varying intervals, violent eruptions have occurred. In an eruption of 1669, the torrent of lava inundated a space of fourteen miles in length, and four in breadth, burying beneath it five thousand villas and other habitations, with part of the city of Catania, and at length falling into the sea. During several months before the lava burst

out, the old mouth, or great crater, was observed to send forth more smoke and flame than usual, and the top fell in, so that the cone became much lowered.

In 1809, twelve new craters opened, about half-way down the mountain, and threw out rivers of burning lava, by which several estates and farms were covered to the depth of thirty or forty feet; and in 1811, other vents appeared on the eastern side, and discharged torrents of liquid lava with amazing force.

145. In 1832, a violent paroxysm took place, and continued with but little intermission for several weeks. On the 31st of October, in the middle of the night, there arose, without any previous indication, a column of smoke and flame from the base of the large cone on the northern side; and, shortly after, an immense quantity of fluid matter was discharged from the crater, on the western side, divided into numerous streams. Next morning, repeated earthquakes, the increased noise of the lava, which now flowed rapidly, and the immense volumes of thick black smoke at the foot of Monte Scavo, announced that the eruption had greatly increased in violence, and several streams of lava were seen descending. On the 2nd of November, contrary to all expectation, the eruption ceased, and the lava was found to be so far cooled, that several adventurous observers were enabled to get upon it, and walk a few paces. On the 3rd, the hope that the fire was almost extinct was nearly certain; but in the evening, a violent earthquake, followed by several others less violent, with an increased quantity of smoke, foreboded an eruption; and two hours before midnight, another severe shock occurred, and was succeeded by black smoke mingled with flames, and incessant thunder.

"Having approached," says Signor di Luca, "as nearly as was prudent, to the hollow from which the fire issued, we found four apertures, which threw out burning matter. Raising our eyes from these vents, we observed a cleft or rent, about a mile in length, from which volumes of smoke arose from time to time; and, as at the bottom it reached the openings above-mentioned, it enabled us to behold the burning furnace in the interior of the mountain. Meanwhile the thunder was incessant, and the detonations were terrible; the lava continued to flow, and enormous masses of red hot substances were thrown to a great height mingled with vast volumes of flame and smoke. The shocks of earthquake were likewise so violent, that horses and other animals fled in terror from the places where they were feeding."

146. But by far the most interesting feature of Etna is an immense depression or excavation on the eastern side of the mountain, called the *Val del Bove*. This vast plain, or rather circular hollow, is five miles in diameter, and from two to three thousand

feet in the height of its bounding precipices, which in most places are nearly perpendicular. This remarkable area appears to have resulted from the giving way and subsidence of part of the crust of the volcano, from some violent action in the interior, which occasioned the sudden removal of an enormous mass of mineral matter. This plain is encircled by subordinate volcanic mountains, some of which are covered by forests, while others are bare and arid like many of the cones of Auvergne. The walls or cliffs surrounding this depression are formed of successive layers of lava of variable thickness, with interposed beds of tufa, ashes, and igneous conglomerates of different colours and degrees of fineness. They slope downwards towards the sea at an angle of from twenty to thirty degrees, and have evidently been formed at various intervals by successive eruptions from the top of the mountain, and were continuous before the subsidence took place which gives this region its present character.

The perpendicular sides of this natural amphitheatre are everywhere marked by vertical walls or dykes, which not only intersect the concentric sheets of lava and tufa, but, standing out in bold relief, like prodigious buttresses, impart a most extraordinary character to the scene; the greater induration of these intruded dykes having enabled them to resist the denuding action which has removed the less coherent pre-existing erupted materials. These buttresses are from two to twenty feet in thickness, and being of immense height, are extremely picturesque; some of them are composed of trachyte, and others of blue compact basalt with olivine. The surface of the plain is wild and desolate in the extreme, presenting the appearance of a tempestuous sea of liquid lava, suddenly congealed. Innumerable currents of lava are seen piled one upon the other, some of which terminate abruptly, while others have extended across the Val, and descended in cascades into the lower fertile regions, where they are spread out in sterile tracts amid the vineyards and orange groves.*

147. A section of Mount Etna, extending north and south between Catania on the south, and Taorminia on the north, is

Fig. 62.—Mount Etna.

shown in fig. 62; the east, upon the slope of which the cavity in question is observable, being presented to the observer.

* See Captain Basil Hall's graphic description of a visit to the Val del Bove, "Patchwork," vol. iii. p. 31.

A ground-plan of the Val del Bove and the surrounding parts of the mountain is shown in fig. 63.

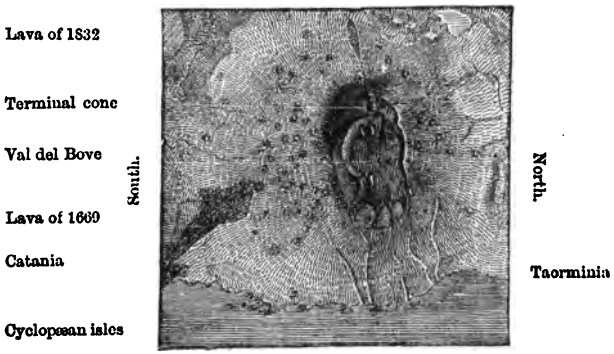


Fig. 63.—Plan of the Val del Bove, Mount Etna.

148. The sudden sinking of the ground by which these crater-formed cavities are produced, is often attended with the sudden production of lakes, filling such cavities with water from subterranean sources. Such lakes are sometimes supplied with water at a high temperature, as was the case in one produced in 1835 in Cappadocia, near the ancient Cæsarea, and in 1820 in the island of St. Michael, one of the Azores.

149. Volcanic islands generally are found to affect the semi-lunar form, of which Santorin, fig. 58, is an example. Thus the island of Sabrina, already mentioned, which appeared in 1811 among the Azores, at the moment of its rise above the waters presented a crater which opened towards the south and was terminated by crevasses, or openings, from which issued a current of boiling water, figs. 64 and 65.

The island of Julia, which appeared to the south-west of Sicily in 1831, assumed a similar form, and on the 6th of September, 1835, Captain Thayer, the French navigator, found to the north of New Zealand a similar rock recently formed near the surface of the water, which included a lagoon, having a single issue, and within which the water was boiling.

150. These craters of elevation have sometimes continued permanently in the form which they first assumed, but they have also frequently been subject to subsequent changes of form from age to age. The case of Vesuvius, which underwent a remarkable change in 79 A.D., has been already mentioned. The Peak of Teneriffe rises within a circular enclosure, the sides of which are vertical, and rise to a height of from twelve hundred to two

thousand feet. The volcano of Taal, in the island of Lucon, one of the Philippines, is placed in the centre of a basin filled with

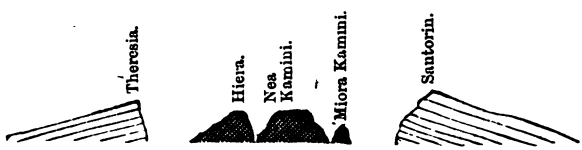
Fig. 64. Forms of volcanic islands. Fig. 65.

water and surrounded by steep and elevated rocks, which leave a single issue from it as in the cases already described.

151. A similar example of this form is presented in the case of Barren Island in the Bay of Bengal (fig. 66, p. 65), which consists of a circle of high mountains, into which the sea flows through a single opening, and of which the centre is occupied by a volcano two thousand feet high, which was in full activity at the time of the discovery of the island.

152. The islands of Santorin and Theresia, already described, form probably the borders of vast craters of elevation. Ancient historians cite them as having appeared long before the Christian era, after a succession of violent earthquake shocks, and in accordance with this tradition, they present strata inclined outwards, as shown in fig. 67; the islands more recently elevated

Fig. 67.



having issued from the middle of the crater. The strata observed in Santorin and Theresia, are inclined from the centre in accordance with the principle explained in (140).

Fig. 72.—THE SALSES, OR MUD VOLCANOES, OF CARTHAGENA.

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER VI.

153. Form of craters.—154. Stromboli—Formation of internal adventitious cones and craters.—155. Strata of lava—how formed.—156. Formation of lava n dykes.—157. Salses, or mud volcanoes.—158. Fumarolles.—159. Geysers.—160. Valleys of elevation.—161. Formation of parallel ridges.—162. Slow operation of air, water, and heat.—163. Atmospheric effects upon rocks.—164. Effects of water on rocks.—165. Effects of the sea on cliffs.—166. Effects of waterfalls.—167. Effects of the sea and of icebergs on the forms of rocks.—168. Geological phenomena explicable by natural causes still in operation.—169. Portland dirt-bed—Its organic deposits.—170. Climate of England tropical at the epoch of these deposits.—171. Example of coal deposits.—172. Northumberland coal mines.—173. Colliery near Wolverhampton.—174. Deposits in Treuille mine at St. Etienne.—175. The character of the waters shown by the organic deposits—Fossil shells.

153. IT has been impossible to obtain direct observations of the interior of craters when in a state of active eruption, but when they have been approached immediately after the cessation of an

eruption, these cavities appear to have generally a conical form, the base of the cone being presented upwards, and the lower part filled with consolidated lava, by which the principal chimney of the crater is covered. Sulphurous vapour is observed to issue from its fissures and interstices, sometimes several open gulfs are seen, from some of which vapours are emitted, and at the bottom of others incandescent lava is seen. Others again are silent and dark, and inspire an indescribable sense of terror.

154. The crater Stromboli, which has been in activity since the most ancient times, presents at present the same appearances as those which were described by Spallanzani, in 1788. It is constantly filled with lava in a state of fusion, which alternately rises and falls in the cavity. Having ascended to ten or twelve yards below the summit of the walls, this boiling fluid is covered

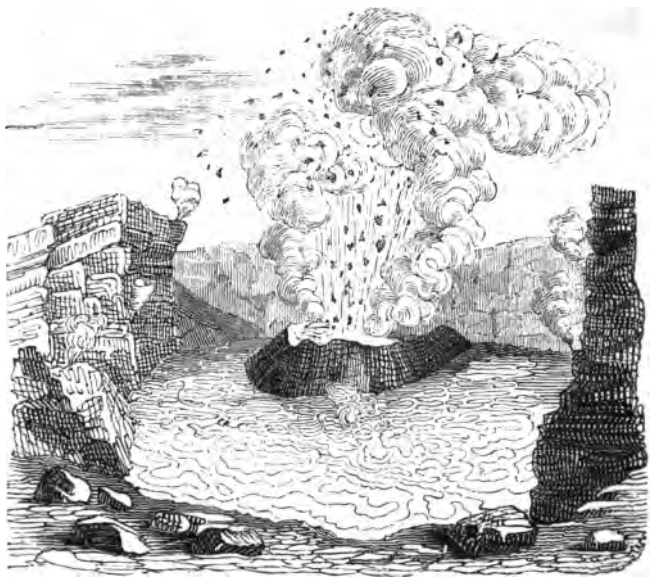


Fig. 67.—Vesuvius in 1829.

with large bubbles, which burst with noise, letting enormous quantities of gas escape from them, and projecting on all sides scoriaceous matter. After these explosions, it again subsides, but only to rise again and produce like effects—these alternations being repeated regularly at intervals of some minutes. In craters

where the lava is less fluid than in that of Stromboli, new cones are sometimes formed in the midst of the crater, which first rise in the form of a dome, and then burst out so as to form a small active volcano in the middle of the crater of the great one. This phenomenon is often presented within the crater of Vesuvius (fig. 67) and was more particularly witnessed in 1829.

155. Sometimes the lava, which is pressed upwards instead of being violently ejected, spreads itself in a sheet of greater or less thickness over the surface (fig. 68) where it hardens, and is subsequently covered by other deposits. Cases have been found also where a succession of these strata, formed at different intervals, with interposed strata of other matter, have been observed (fig. 69). In such cases the matter forming the superior stratum is seen to

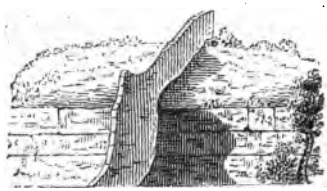
Fig. 68.

Fig. 69.

have passed in a liquid state through the inferior strata previously described.

156. It often happens that the lava is solidified in clefts, which are nearly vertical, and thus forms walls, called *dykes*, which frequently rise to the surface. In such cases the solidified lava, being much harder and less susceptible of degradation from atmospheric and aqueous influences, remains standing when the matter surrounding it is swept away, and thus forms a wall rising above the general surface (fig. 70).

Fig. 70.



157. The phenomena of Salses, or mud volcanoes, has been already briefly noticed in our Tract upon "Earthquakes and Volcanoes," Vol. IV. p. 169. The mud volcanoes are characterised also by the conical form, but their cones are much less elevated, their slopes being flatter (fig. 72). They have at their summit a crater-formed cavity frequently filled with liquid mud, on which large bubbles are continually formed which, bursting, scatter around them earthy matter. There are sometimes, over a surface of little extent, a great number of these cones in full activity, some of which have a height of ten or twelve yards. Sometimes such an assemblage of cones is found at the summit of a mound from fifty to two hundred yards in height, formed of argillaceous

matter, which appears to have been the result of former ejections. The middle is often formed of a lake of mud, the surface of which is more or less consolidated. In certain countries these mounds are found permanently dried, all disengagement of gas, water, and earth having altogether ceased, but it sometimes happens that the same phenomena after long cessation are renewed with violence.

158. Fumarolles and Geysers are the names given to eruptions of steam or boiling water issuing from crevices in volcanic districts, remarkable examples of which are presented in the country surrounding the celebrated volcano of Hecla, in Iceland. Eruptions of hot steam are projected from the crevices of the soil in the form of white columns, rising to heights of from 30 to 60 feet, and often with noise similar to that with which high pressure steam issues from the safety-valve of a boiler. Such phenomena are manifested on a considerable scale in Tuscany, in the neighbourhood of Monte Cerboli, Castel Nuovo, and Monte Rotondo, and are generally disposed in a single line of from 20 to 25 miles in length.

These jets of vapour in all cases include chemical agents, which attack the rocks with which they come in contact; thus the vapour ejected from Vesuvius includes hydrochloric acid, that of the Solfatara, of Pozzuoli, includes sulphurous acid, and that of Tuscany, boric acid.

159. The Geysers are volcanic eruptions of boiling water, some continued, others intermitting, which prevail in immense numbers in Iceland. One of these hot springs is mentioned which, from half-hour to half-hour, projects a column of boiling water 18 feet in diameter to a height of 150 feet (fig. 71).

The water thus ejected contains a certain proportion of silica, which is deposited in a state of hydrate upon all the surrounding bodies, and forms sometimes mounds of considerable extent, at the summit of which is an opening, from which the liquid issues.

Besides silica, the water of the geysers also contains, in a small proportion, the carbonates or sulphates of soda, ammonia, potash, and magnesia, besides a minute proportion of carbonic acid.

160. Calcareous as well as volcanic countries present vast depressions of the ground analogous to craters, but instead of being nearly circular like those of volcanoes, they are most frequently oblong and very irregular. Such cavities are frequent in the mountains of the Jura. These are generally oblong hollows, like clefts, which sometimes extend to a great distance, forming oblong mounds parallel to each other, with salient summits. These depressions or cavities (fig. 73) have received the name of

valleys of elevation, though they differ in nothing except their form from craters of elevation.

Fig. 73.

161. Elevations of the superficial crust often take place in a series of parallel lines forming so many parallel ridges with intermediate hollows, as if an upheaving force had been exerted by the subjacent strata in a series of parallel directions vertically under the ridges thus produced. The Jura mountains present great numbers of examples of this (fig. 74).

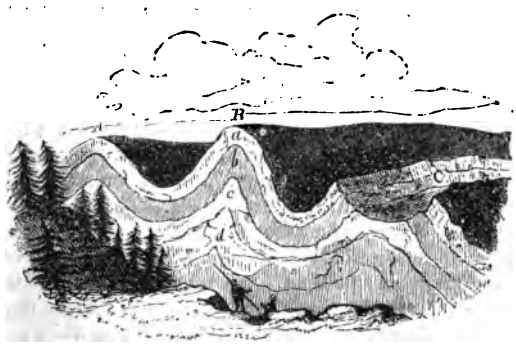


Fig. 74.—Section of ridges in the Jura Mountains.

162. The changes in the condition of the earth's surface attending the undulations and disruptions of its crust, which have been noticed above, excite attention because of the sudden catastrophes which often attend them, and the wide devastation which they sometimes spread. There are, however, other agencies exterior to the surface, of which the accumulated effects, produced in long intervals of time, are not less important. The principal of these are air, water, and heat, acting separately or together, upon the solid matter of the external surface of the terrestrial crust. These operate mechanically by fracture and abrasion, physically by dissolution and disintegration, and chemically by decomposition.

The waters of the ocean evaporated by heat rise into the superior parts of the atmosphere, and are carried by atmospheric currents in their course towards the most elevated parts of the land, where they are condensed, and upon which they are precipitated in the liquid state; thence they descend along the declivities, forming rivers and lakes, and sometimes penetrating the crust so as to form springs, until at length, sweeping over the land, they return to the deep, carrying with them, however, a large quantity of detritus of the solid crust, over which they have passed, and which they deposit in the bottom of the sea to form new systems of strata.

Independently of water, air itself by its mechanical action upon solid matter detaches, fractures and abrades more or less of it. The water suspended in the form of vapour in the atmosphere penetrates the pores and interstices of rocks to a greater or lesser extent, according to their density and structure. In times of drought it is again expelled by evaporation, and being thus alternately and incessantly absorbed and dismissed, it at length disintegrates the superficial strata of the rocks, to whatever depth it may penetrate.

Such effects are observable in all cases where extensive sections of the solid crust are made, whether by natural or artificial causes. They are thus seen upon the face of the cliffs which overhang the sea, in the escarpments of ravines which pass through mountain-chains, and in the sides of the vast cuttings artificially produced in quarrying, and still more in the construction of roads, railways, and canals. These effects are, of course, the more prompt and sensible, as the matter composing the rocks is more susceptible of imbibing humidity and of being deprived of it by evaporation. All mountains exhibit traces of such effects in some forms, determined by the various degrees in which their strata are susceptible of them. Thus, while some, like volcanic cones, assume uniform slopes in a conical form, fig. 75 A; others, those composed of gneiss, for example, assume the forms of pointed and dentated peaks, fig. 75 B. Numerous examples of

Fig. 75.

A B C D

these are seen in the chains of the Alps, where they take the names of *needles*, *teeth*, and *horns*, (aiguilles, dents, and cornes,),

according to their varying forms. Calcareous cliffs assume cylindrical forms, fig. 75 C, which seem at a distance to resemble fortifications. The faces of these cliffs are often worn into a succession of terraces or steps, as in fig. 75 D.

163. The effects of long-continued atmospheric action upon the forms of solid rocks, are seen in many places on the surface of continents, which the sea has not approached within historic times. Certain granites are thus disintegrated so profoundly, as to reduce the under-surface of the strata to a mass of gravel, forming holes into which the pluvial water from ravines flows in all directions. These rocks are also sometimes met with worn into rounded forms, and piled one upon another, so as to be supported only at a single point, forming what are popularly called *rocking-stones*, fig. 76 B. Cases of this kind are especially presented in the case of certain porphyritic granites. In mountains where granite is decomposed with facility, it has been remarked that masses of these rocks, more or less divided, present a sort of horizontal layers, separated by vertical fissures, so as to reduce the whole to a pile of irregular parallelopipeds, fig. 76, C. The angles and edges being often worn away, the mass is reduced to a form resembling a pile of cheeses, fig. 76 A.

Fig. 76.

A B C

164. Solid rocks are often traversed by vertical crevices filled with matter more easily penetrable by water. In such cases, the pluvial waters entering these crevices dissolve and ultimately sweep away the matter which fills them, leaving the parts thus separated without support. These ultimately fall to the foot of the cliff (fig. 77).

165. When waters bathe the foot of steep cliffs, they have a tendency to dissolve and decompose their lower strata, leaving

the superior ones undisturbed and, consequently, overhanging. When this action is continued to a certain point, the cliffs thus overhanging fall by their weight (fig. 78).

It sometimes happens that the accumulation of the débris of such cliffs which takes place below them, operates as a barrier to the waves, and so, for a time, protects them from further degradation (fig. 79). In some cases the natural form of the rocks exposed to the action of the waves enables them to resist these effects, and such forms are accordingly often imitated in the construction of harbours and breakwaters (fig. 80).

Fig. 77.

166. Cascades have often the same effect in the degradation of the cliffs over which they fall, as have the action of waves directed against their base. When such cliffs are formed of

Fig. 78.

alternate calcareous and argillaceous matter, the former, being more susceptible of disintegration than the latter, absorbs and is

Fig. 79.

Fig. 80.

worn away by the water either in its fall, or by its recoil from the foot of the cascade; the cliff, therefore, over which the torrent falls soon overhangs (fig. 81) and at length is broken off by its weight.

167. It is to the operation of such causes, as well as to the action of icebergs floating from the Pole, that various forms of rocks found in the ocean, but more especially in the neighbourhood of continents, must be ascribed. The action of the sea disintegrates the softer parts, leaving the harder standing, and thus forms the most capricious are produced. Wide clefts and openings are made between solid rocks through which the sea passes, and in some cases the rocks are broken into rude and irregular columns and needles (figs. 82 and 83.)

Fig. 81.

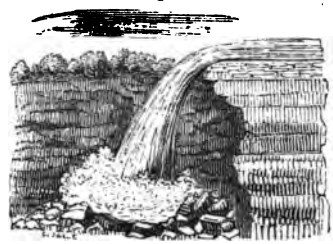


Fig. 82.

Fig. 83.

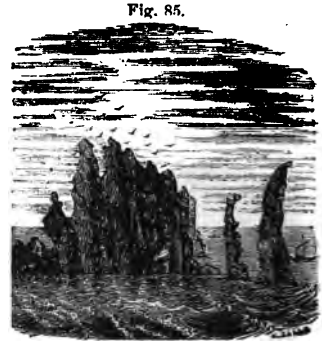
Other similar examples are presented in the case of the chalk-cliffs near the French village of Etretat on the Channel coast (fig. 84) and also in the porphyritic and granitic columnar rocks of the Shetland Isles (fig. 85).

168. Thus, in fine, it appears that there are, and constantly have been, within historic times, natural agencies in operation upon the surface of the globe, sufficient to explain all those phenomena observed by modern geologists, which, when first brought under notice, excited sentiments of such unmixed wonder. Alternate elevations and depressions of the earth's crust, either sudden or gradual, are recorded in all times; and it is easy to imagine that, in proportion as the shell of solid matter which incloses the igneous central fluid was less and less thick, and

consequently less and less resisting, so at more and more remote periods, these undulations, and their consequent disruptions and explosions, must have been much more frequent, and attended by catastrophes infinitely more violent. The volcanic eruptions which have taken place within historic times, may be regarded as miniature reproductions of the phenomena of which the globe was the theatre at much more remote geological dates. The wear, abrasion, decomposition, and transport of the solid materials of the earth's crust by the action of atmosphere and the waters of the ocean, when continued through periods compared with which that limited by the existence of the human race is but a unit, can easily be imagined to have produced all the effects which are visible on the earth's surface, and to greater or less depths within its crust. The deposits formed by the detritus of the land

Fig. 84.

Fig. 85.



carried by the currents of rivers to their embouchures, exhibit on a small scale the stratification produced by pre-Adamite seas. In a word, all the geological phenomena discoverable by the sections, natural or artificial, of the earth's crust, admit of clear and satisfactory explanation, by merely imputing to the physical agents now in operation an energy proportional to the diminished thickness of the earth's crust, and effects due to a continuance of action for periods of time, compared with which the common chronological units must be regarded as insignificantly minute.

Having thus briefly indicated the natural causes to which geological phenomena must be ascribed, we shall resume the subject which we had dropped, and continue our notice of some of these results, which illustrate the past condition of the earth.

169. There exists in England, in the Isle of Portland, as well as elsewhere, and on various parts of the continent, a stratum called by miners and quarrymen the "*dirt-bed.*" This consists of

a layer about one foot in thickness, composed of dark brown friable loam, containing a large proportion of earthy lignite, and, like the recent soil of the island, many water-worn stones and pebbles. It seems to have been a bed of vegetable mould, which at a remote geological epoch supported an abundant and luxuriant vegetation, for we find in it and upon it innumerable trunks and branches of cone-bearing trees and cycadeous * plants. Above this bed are found layers of finely-laminated cream-coloured limestones, the total thickness of which is about ten feet, and upon which is deposited the modern vegetable soil; but this latter at present, instead of supporting cycadeous plants and pine forests, barely maintains a scanty vegetation.

The most remarkable circumstance attending this dirt-bed, as it is called, is the position of the trees and plants found on it. They are still erect, as though they had been suddenly petrified while growing in their native forests, with their roots in the vegetable soil and their trunks extending into the limestone above it.

Immediately below it is a thick stratum of fresh-water limestone, of little value for building; and below this again is the stratum of the celebrated Portland stone so extensively used for that purpose. The consequence is that the dirt-bed and its interesting materials, little regarded by quarrymen, are cast away and scattered about as mere rubbish, in order to get at the layer of building-stone which lies below them. "On one of my visits to the island (in the summer of 1832)," says Dr. Mantell, "the surface of a large area of the dirt-bed was cleared, preparatory to its removal, and the appearance presented was most striking. The floor of the quarry was literally strewn with fossil wood, and before me was a petrified forest, the trees and plants, like the inhabitants of the city in Arabian story, being converted into stone, yet remaining in the places which they occupied when alive! Some of the trunks were surrounded by a conical mound of calcareous earth, which had evidently, when in a state of mud, accumulated round the stems and roots. The upright trunks were generally a few feet apart, and but three or four feet high; their summits were broken and splintered, as if they had been snapped or wrenched off by a hurricane, at a short distance from the ground. Some were two feet in diameter, and the united fragments of one of the prostrate trunks indicated a total length of from thirty to forty feet; in many specimens portions of the branches remained attached to the stems. In the dirt-bed, there were numerous trunks lying prostrate, and fragments of branches.

"The external surface of all the trees I examined was weather-

* Such as palms and ferns.

worn, and resembled that of posts and timbers of groins or piers within reach of the tides, and subjected to the alternate influence of the water and atmosphere; there are but seldom any vestiges of the bark.

"The fossil plants related to the recent Cycas and Zamia,* occur in the intervals between the pine-trees; and the dirt-bed is so little consolidated, that I dug up with a spade, as from a parterre, several specimens that were standing on the very spot where they originally grew, having, like the columns of the temple of Pozzuoli, preserved their original erect position amidst all the revolutions which have subsequently swept over the surface of the earth, and buried them beneath the accumulated detritus of innumerable ages. These fossil plants, though related to the recent Cycadeæ, belong to a distinct genus.† There are two species—one is short, and of a spheroidal form (M. nidiformis); the other is longer, and subcylindrical (M. cylindrica). ‡

"The trees and plants are completely silicified, and their internal structure is beautifully preserved in many examples; the wood, microscopically examined, displays the organisation of the Araucaria. A cone has been found in the dirt-bed, which Dr. Brown considers to be nearly related to the fruit of the Norfolk Island pine (Araucaria excelsa). The Portland and Isle of Wight fossil trees appear to belong to the same species of Coniferæ." §

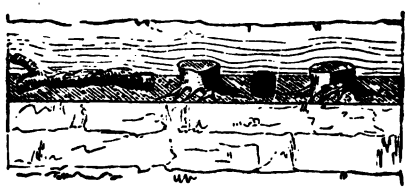


Fig. 86.—Section of the Portland dirt-bed.

170. The presence of plants analogous to the modern Cycas and Zamia shows that the climate of England, at the time when the vegetation of this stratum flourished, must have been

* These plants are so common in conservatories that their general appearance must be familiar to the reader. In the Botanic Gardens at Kew there are magnificent specimens of Cycas and Zamia, and of other plants of hot climates, of which related forms occur in the Wealden.

† Named by M. Adolphe Brongniart, *Mantellia*.

‡ Specimens of the former species are called "*crows'-nests*" by the quarrymen, who believe them to be birds' nests originally built by crows in the pine-trees, and which have since become petrified.

§ Mantell, p. 387.

analogous to that of the tropics, a fact which is in conformity with what has already been explained.

171. The coal deposits are everywhere attended with similar results. Entire trees are found, some of which are standing upright with their roots penetrating the stratum below them, exactly as they penetrated the soil on which they grew. Several examples of these have been presented in England, one of the most remarkable of which occurred in the construction of the railway between Manchester and Bolton. Near Dixonfold five large stems of Sigillariæ were found erect with their roots striking into layers of clay below. They stood upon the same level one beside the other, the trunks being surrounded and filled by soft blue shale, and the carbonised bark being all that remained of the original structure. All these trunks seemed to have been broken violently off at a point four or five feet above the roots, no traces of the upper parts of the trees being discovered.

172. On the coast of Northumberland, within a space of half a

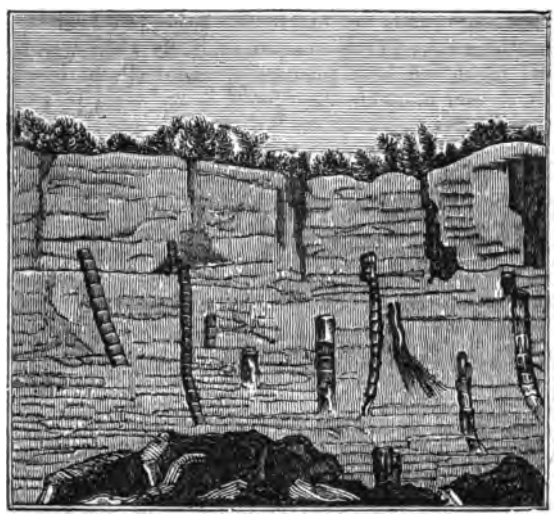


Fig. 87.—Section of the Treuille Mine at St. Etienne.

mile in length, twenty upright trees were discovered by Mr. Trevelyan, and similar ones were found in the same coal-field at some distance, as if they had been the continuation of a submerged forest like that of the Isle of Portland.

In the Newcastle coal-field a stratum of sandstone occurs

nearly five hundred feet below the surface, on which numerous trees have been found standing erect from two to eight feet in circumference, with their roots struck into thin layers of coal.

173. "In a colliery near Wolverhampton," says Hugh Miller, "the bottom coal rises to view, and where the surface has been cleared of the alluvial covering, it presents the appearance of a moor on which a full-grown fir-wood had been cut down a few months before, and only left the stumps behind. Stump rises beside stump, to the number of seventy-three in all: the thickly clinging roots strike out on every side into what seems once to have been vegetable mould, but now exists as an indurated brownish-coloured shale. Many trunks, sorely flattened, lie recumbent on the coal; several are full thirty feet in length, while some of the larger stumps measure rather more than two feet in diameter. There lie, thick around, Stigmariæ, Lepidodendra, Calamites, and fragments of Ulodendra; and yet with all the assistance which these lent, the seam of coal formed by this ancient forest does not exceed five inches in thickness. Not a few of the stumps in this area are evidently water-worn. The prostrate forest had been submerged, and molluscs lived, and fishes swam over it. This upper forest is underlaid by a second, and even a third: we find three full-grown forests closely packed up in a depth of not more than twelve feet." *

174. M. Alexandre Brongniart † describes a coal-pit at Treuille near St. Etienne, in the neighbourhood of Lyons, which contains enormous stems of Calamites and other trees in erect positions (fig. 87). These and similar effects are considered as proofs that the coal was produced by the submergence of a forest which grew upon the spot. This particular mine is very favourable for observations being in the open air, and presenting a natural succession of the strata of clay, slate, and coal, with four layers of compact iron-ore in flattened nodules, accompanied and even penetrated by vegetable remains.

The upper ten feet of the quarry consist of micaceous sandstone, which is in some instances stratified, and in others has a slaty structure. In this bed are enormous vertical stems traversing all the strata, and appearing like a forest of plants resembling the bamboo or large *Equiseta* petrified on the spot on which they grew. The stems are of two kinds, one long and thin, from one to four inches in diameter, and nine or ten feet high,

* First Impressions of England and its People, by Hugh Miller, p. 223.

† Notice sur les Vegetaux fossils traversants les Couches du Terrain houilleux, par M. A. Brongniart, Paris, 1821.

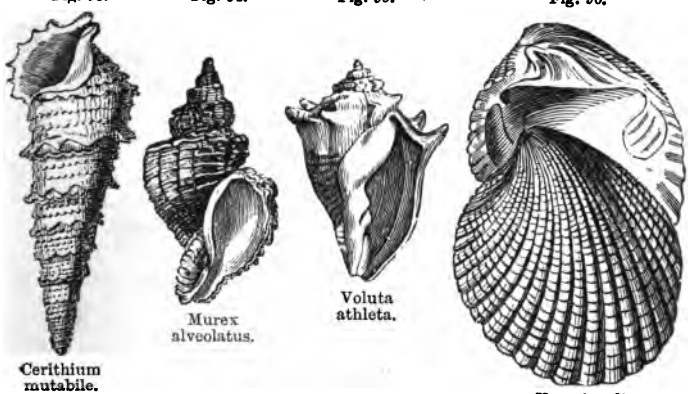
consisting of jointed and striated cylinders with a thin coaly bark. The other and less common species consist of hollow cylindrical stems spreading out from the base like a root.

Fig. 88. Fig. 89. Fig. 90. Fig. 91. Fig. 92.

Limnea longiscata. Planorbis evonphalus. Paludina lenta. Melania.

175. The character of the waters, according as they may have been fluviatile and lacustrine or marine, from which the several strata forming the crust of the earth were deposited, is betrayed

Fig. 93. Fig. 94. Fig. 95. Fig. 96.



Cerithium mutabile. Murex alveolatus. Voluta athleta. Venericardia imbricata.

by the nature of the organic remains which these strata severally contain. Thus, if we find shells (figs. 88 to 92) analogous in their character to existing fresh-water shells, it may be inferred that the deposits were fluviatile and lacustrine, or at all events that they were fresh-water deposits.

If, on the other hand, none but marine shells (figs. 93 to 96) be found in any stratum, it may be inferred that such stratum was submerged by the ocean from which the deposits were made.

In cases where the organic remains are of a mixed character, containing shells and other fossils, some analogous to existing marine and other species, it may be inferred that such deposits were made at the embouchures of rivers.

By such inductions it has been ascertained that extensive tracts of the surface of the globe, which are now dry land and raised to elevations considerably above the level of the sea, must, at various former epochs, have been submerged in the waters of the ocean. A great part of France, including the country around Paris, Normandy, Artois, Picardy, Franche-Comté, Burgundy, the Cevennes, Dauphiny, and Provence, present examples of this.

Fig. 108.—Fossil footprints in the strata of the new red sandstone.

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER VII.

176. Fossil foraminifera—177. Fossil infusoria—Researches of Ehrenberg.—178. Marine deposits at great heights, produced by former undulations of the land.—179. Organic deposits show that the same parts of the land have undergone a series of alternate elevations and depressions.—180. Example of the Portland beds.—181. Fossil footsteps.—182. Such traces common in the new red sandstone, at Hesseburg, and near Liverpool.—183. Footprints of birds.—184. Fossil rain-drops and ripple-marks.—185. Conclusion.

176. Besides the larger class of fossil shells, there are numerous infinitely more minute ones, which have largely contributed to the formation of the actual crust of the globe, the principal of which are the Foraminifera and Infusoria.

The Foraminifera are marine animals of low organisation, and generally of such extreme minuteness, that an ounce of sea-sand will contain three or four millions of them. The body consists of uniform granules enclosed in a skin or membrane

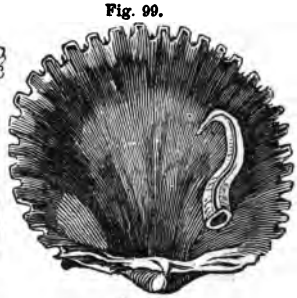
Fig. 97.

Nautilus truncatus.

Fig. 98.

Ammonites catena.

Fig. 99.



Serpula.

having one or more cavities or digestive sacs. These animals are regarded as *polypes*, and are protected by shells. Some of these shells, such as the Orbiculina, contain a single cell. Others, such as the Nodosaria, consist of several cells disposed in conical or cylindrical directions. Other families have shells, like that of the Nautilus, consisting of a succession of cells in spiral forms.

The Foraminifera derive their name from the structure of the shell, which consists of one or more series of chambers separated from one another by septa or partitions, in each of which there is a small perforation called a foramen.

Some specimens of these shells, on a highly magnified scale, are given in figs. 100 to 106.

These microscopic shells, of which from seven to eight hundred fossil species have been discovered, are accumulated in enormous numbers in the strata of the earth, and, in many cases, exclusively form very considerable calcareous deposits, of which the chalk and the cretaceous and tertiary strata present numerous examples in all parts of the world.

177. The Infusoria, the existing species of which are found in

fresh and salt water, are smaller still than the Foraminifera, being only visible by the aid of microscopes of great magnifying power. There are innumerable species of them, which are furnished with siliceous shells, and which, consequently, are accumulated at the bottom of the waters with the contemporaneous microscopic plants. Now, although these beings are so minute that forty thousand millions of them would not fill a space of

Fig. 100. Fig. 101. Fig. 102. Fig. 103.

a b a b c a b a b

Fig. 100.—*a*. Nodosaria limbata.
b. Internal arrangement of the cells.
101.—*a*. Marginulina trilobata.
b. The last cell seen from above.
c. The internal arrangement of the cells.
Fig. 102.—*a*. Flabellaria rugosa.
b. Side view, to show the flatness.
,, 103.—*a*. Textularia turris.
b. Internal arrangement of the alternate cells.

more than a cubic inch, M. Ehrenberg has demonstrated that their accumulation in certain parts of the earth's crust has pro-

Fig. 104. Fig. 105. Fig. 106.

a b

Fig. 104.—Rotulina Voltzii.
,, 105.—*a*. Cristellaria rotula.
Fig. 105.—*b*. Edge view, to show the flatness.
,, 106.—Orbiculina numismalis.

duced strata several yards in thickness, and of vast extent; and that in many other cases strata not less extensive are formed by their combination with other conchiferous animalcules. They constitute almost exclusively the polishing slate of Bilin, in Bohemia, which occupies a surface of great extent, probably the site of an ancient lake, and forms a stratum fourteen feet in thickness, composed of the mineralised shields of these animalcules. "The diameter of a single one of these creatures," says M. Ehrenberg, "amounts upon an average, and in the greatest part, to the 3500th of an inch, which equals $\frac{1}{8}$ of the thickness of a human hair, reckoning its average size at the 570th of an inch. The globule of the human blood, considered at the 3600th of an inch, is not much smaller. The blood globules

of a frog are twice as large as one of these animalcules. As the Polirschiefer of Bilin is slaty, but without cavities, these animalcules lie closely compressed. In round numbers, about twenty-four millions would make up a cubic line, and would, in fact, be contained in it. There are 1728 cubic lines in a cubic inch; and therefore a cubic inch would contain, on an average, about forty-one thousand millions of these animals. On weighing a cubic inch of this mass, I found it to be about 220 grains. Of the forty-one thousand millions of animals, a hundred and eighty-seven millions go to a grain; or the siliceous shield of each animalcule weighs about $\frac{1}{187}$ millionth part of a grain."

The remains of these Infusoria are often found in abundance in flints, opals, and more especially in the earthy matter which envelopes the translucent parts. They exist in large quantities, also in most marls, especially in those of lacustrine depositions in calcareous slates of the same formation, and in all chalk strata. They form the chief part of the deposits which fill the gulfs and arms of the ocean, and are found in all the earthy deposits raised from the bottom of the waters in ancient and modern times. They exist in strata sixty feet thick in the low plains of Western Germany, at a depth greater or less under the sands of those countries. It is a remarkable fact, that one of the strata on which the city of Berlin is placed, is formed of the shells of Infusoria which still live and are propagated and sustained, doubtless, by the waters of the Spree, on which that city is built.

M. Ehrenberg has described numerous fossil genera and species of Infusoria found in all parts of the world, and in different strata, a few of which are represented on a high magnified scale in fig. 107.

178. At whatever heights upon the land fresh-water shells and the remains of land animals may be found in the sedimentary strata, no surprise can be excited, since it is perfectly conceivable that at various epochs any portions of the land, whatever be its level, may have been submerged by lakes or overflown by rivers. But we find, also, at all levels, no matter how high, even at the summits of lofty ranges of mountains, marine deposits in strata of immense extent and vast thickness.

179. In many places an analysis of the strata shows the most curious alternations between fresh-water and marine deposits, which can only be explained by the supposition that the crust of the globe at these places has undergone a succession of elevations and depressions, and that after being submerged for an indefinite period, and receiving marine deposits, it was then upheaved so as to become dry land; and that during another indefinite period it was peopled by land and fresh-water animals, and covered with a

certain vegetation: that then it was again submerged, either by fresh water or by the sea, receiving during an indefinite period another stratum, either with fluvial and lacustrine remains or with marine deposits, as the case might be; that subsequently it was again upheaved, and again became the theatre of animal and vegetable life upon dry land, and so on.

180. The Portland dirt-beds, already described, prove the existence there, at remote epochs of the globe, of vegetable soil on a land nearly if not altogether dry, beneath which lay a stratum of marine deposits. It follows, therefore, that before this epoch, and before the deposition of the dirt-bed itself with the remains contained on it, that part of the land must have been submerged by the ocean, and that being upheaved, it afterwards became the theatre of animal and vegetable life, such as we find deposited in

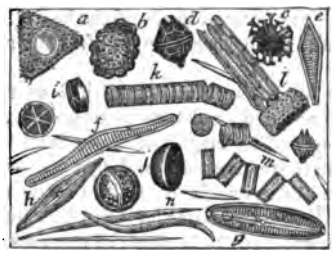


Fig. 107.—Fossil infusoria.

a. Desmidium apiculosum.
b. Euastrum verrucosum.
c. Xanthidium ramosum.
d. Peridinium pyrophorum.
e. Gomphonema lanceolata.
f. Hemanthidium arcus.
g. Pinnularia dactylus.
h. Navicula viridis.
i. Actinocyclus senarius.
j. Pixidula prisca.
k. Gallionella distans.
l. Synedra ulna.
m. Bacillaria vulgaris.
n. Spicula spongiaria.

the dirt-beds. Over the dirt-beds are thick lacustrine deposits of limestone, which lie under the green sandstone, which latter is itself overlaid by the chalk, this latter being evidently a marine formation. Let us see, then, what a curious succession of phenomena is here indicated. The lower marine strata of limestone was first upheaved, and, becoming dry land, was the theatre of rich terrestrial vegetation. It was then submerged by fresh water, and was the place of a lake or deep estuary, in which were formed the strata of limestone, sand, and clay, filled with fluviatile shells, forming a stratum, which from actual observation appears to have a thickness of from seven hundred to a thousand feet. Later still, this was covered by the sea, and marine deposits of green sandstone and chalk were formed upon it, which, at

certain places, had a still greater thickness. In fine, at a later period still, another great elevation of the crust took place, which raised the surface to its present elevation above the waters.

181. Independently of the evidence supplied by organic remains proving that certain strata were at former epochs above the waters and inhabited by land animals, and were subsequently submerged, indications of another order have been supplied by the traces left by animals in the soft surface of the strata, which were afterwards hardened without these traces being effaced. Such traces, therefore, may be regarded as moulds thus accidentally preserved, from which castings might be obtained of those parts of the animals, then living upon the globe, which produced them. Many moulds of shells have been thus found, but the most remarkable indications of this kind consist of the footsteps of certain animals which appear to have been impressed upon the soft surface of the ground, just as the footsteps of any animals might be at present impressed upon the soft sand upon the sea-shore after the retirement of the tide.

182. In 1834 an account was published of remarkable fossil footprints in the new red sandstone at Hesseburg, near Hildburghausen, in Saxony. The largest of these tracks appears to have been made by an animal whose hind-foot was eight inches long, and which, from its resemblance to the human hand, received from Professor Kaup the name of Chirotherium. Some of the tracks, however, appeared to be those of tortoises; and Link suggests that others are those of some colossal species of frog or salamander, fig. 109.

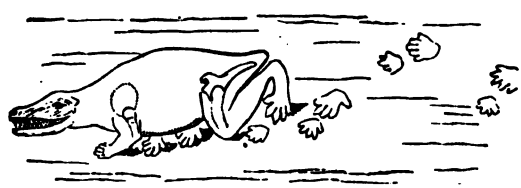


Fig. 109.—Labyrinthodon pachignatus (Owen).

The traces represented in fig. 108 are those found in a sandstone slab at Hesseburg. Various similar tracks have been found in the sandstone quarries at Storeton Hill, near Liverpool. The largest footprint was nine inches long and six inches broad, the length of the step being nearly two feet. Similar tracks were found by Professor Hitchcock in the quarries of Connecticut; and Mr. Scrope found similar marks on a surface bearing ripple-marks in the vast marble-quarries near Bath.

These last are supposed to have been made by some crustaceous animal crawling along the bottom of an estuary; for between the rows of footprints are in some cases observed the impressions of the belly, and in others the trail of the tail.

183. Footprints of birds have been discovered in several quarries in the valley of the Connecticut river, and also in different parts of the state of Massachusetts. Several specimens of these are now in the British Museum. The most remarkable of these is a slab, eight feet by six, exhibiting various tracks of birds, (fig. 110).

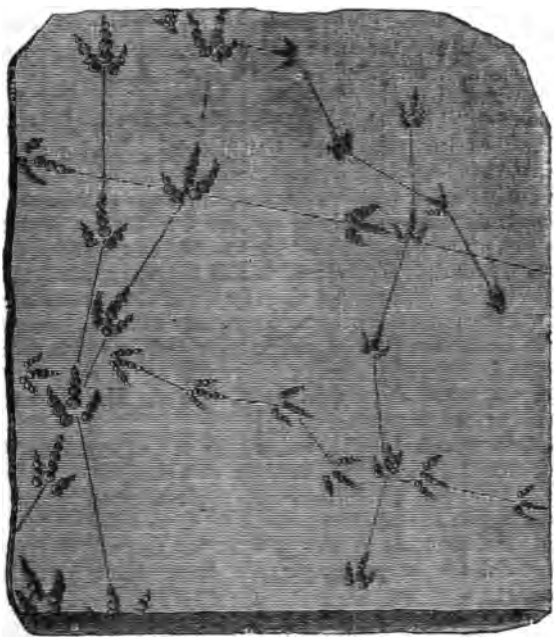


Fig. 110.—Fossil footsteps of birds.

All these marks belong to the birds called *waders*, and appear to have been made upon the sea-shore. Some are small, others of a size so enormous that they could only have belonged to birds twice the size of the largest ostrich. In one case the footprint measures fifteen inches in length by ten in width, without counting the hind-claw, which itself measures two inches. The distance

between the successive footprints varies from four to six feet. The shorter footsteps may be taken as the length of the step when the bird walked at its ordinary pace, and the larger one when it moved more swiftly.

184. A very remarkable concomitant of some of these fossil footprints is the distinct impressions of rain-drops upon the strata. Dr. Dean discovered a stratum containing more than a hundred marks of the feet of birds of various species, the whole surface of which was pitted by the marks produced by a heavy shower of rain. Like marks were observed in Storeton quarry, near Liverpool. The impressions produced by the rain-drops were sometimes perfect hemispheres, an indication of a heavy fall of rain in a vertical direction, and consequently in a calm atmosphere. In other cases the impressions were irregular and oblong, as if the drops had struck the surface obliquely, as when a shower is accompanied by a strong wind.

Professor Hitchcock also mentions specimens of sandstone obtained from various parts of the United States, showing at once footprints, ripple-marks, and rain-drops, the latter being elongated by the direction of the wind when the shower was falling.

These phenomena can only be explained by the fact that the marks were made upon the moist sand formed on the shores of an estuary or tidal river, between high and low water mark, which then was allowed to dry and harden by the action of the sun and air between two successive tides. The waters on the return of the tide would wash up silt to cover up the impressions without impairing their accuracy; the two layers uniting so as to exhibit when separated the one a shield, and the other a cast from it of the form thus impressed.

185. Our necessary limits, rather than the exhaustion of the subject, compel us here to close these first glimpses of geology. We propose, however, in a succeeding paper, to resume the subject, and to give a brief sketch of the History of the Earth from the first formation of its solid crust to the last great act of creation which called the human race and its concomitant tribes into existence.

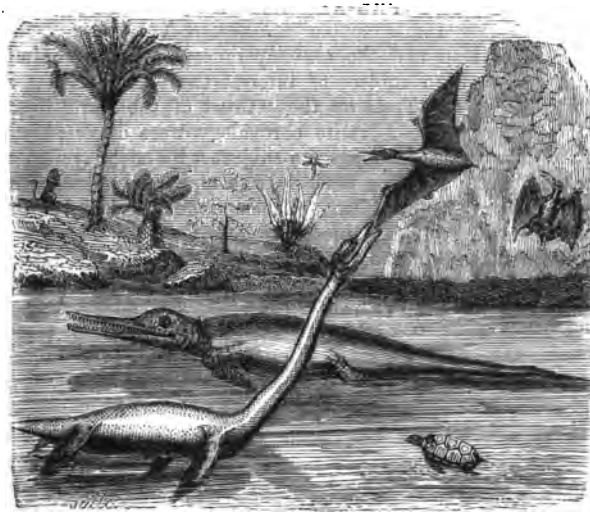


Fig. 161.—ILLUSTRATION OF THE ANIMAL AND VEGETABLE KINGDOMS DURING THE JURASSIC AGE.

THE PRE-ADAMITE EARTH.

CHAPTER I.

186. Interest of the subject.—187. Recapitulation.—188. Original division of the land and water.—189. Uniform temperature at all latitudes.—190. This temperature at first too elevated for organic life.—191. Its gradual reduction.—192. Series of convulsions.—193. Depositions of organic remains.—194. First organic creation after the fourth convulsion.—195. The latest catastrophe of this kind.—196. Method of determining the age of mountains.—197. Ranges of similar date parallel.—198. Their nomenclature.—199. Method of ascertaining the outlines of land and water at each geological epoch.—200. M. Elie de Beaumont's seventeen mountain systems.—201. Their directions and denominations.—202. Manner in which they are grouped.—203. Plan of these systems in Europe.—204. Their geological dates.—205. System of Vendée.—206. System of Finistère.—207. System of Longmynd.—208. System of Morbihan.—209. System of Hundsruck.—210. System of the Ballons.—211. System of the North of England.—212. System of Hainault.—213. System of the Rhine.—214. System of Thuringerwald.

186. THE history of our planet before it was clothed with that variety of vegetation which now adorns it, and became the

habitation of man and the contemporaneous tribes of animals, cannot fail to be a subject of interest the most exciting and profound. In our Tract on the "Crust of the Earth," some glimpses of this pre-Adamite chronology were disclosed. We purpose at present to resume the subject with more system and detail, assuming that our readers have already rendered themselves familiar with the facts, phenomena, and principles which were there stated and explained.

187. Before we enter upon this curious narrative, however, it will be useful to recapitulate the great facts which will be brought in more detail before the reader.

The globe, consisting originally of matter in a state of igneous fusion, being put in a state of rotation, assumed, as a necessary mechanical consequence of that motion, the form which it still retains, called in geometry that of an oblate spheroid, flattened at the poles and bulging out at the equator; the sections made by planes passing through the axis of rotation being therefore ellipses, the longer axes of which are diameters of the equator. We have shown in former Tracts that the eccentricity or degree of the oval shape which characterises these ellipses depends immediately upon the velocity of rotation, so much so that, by mere mathematical calculation, the form of the ellipse has been deduced *à priori* from that velocity, and the form thus calculated has been found to correspond with the actual shape of the earth.

By the gradual process of cooling produced by radiation the surface of the earth became solidified, a thin skin of solid matter being first formed upon it, which, as the cooling continued, became gradually thicker, the increase of thickness being produced by more and more solidified matter collected on its inner surface. This thickness may be said therefore to have increased from the outside inwards. At first the temperature was necessarily such that water could not exist upon it in the liquid state, but according as the temperature of the surface became gradually lower, the aqueous vapour till then sustained in the atmosphere was more or less condensed and precipitated, forming upon it an ocean of uniform depth extending over the entire surface.

188. If no convulsion had taken place the earth would have continued in this state. It would have been one universal ocean undiversified by land, and the human race could never have existed upon it. It follows, therefore, that before terrestrial tribes were created the globe must have been of necessity the theatre of various catastrophes, by which the land was raised above the waters, and by which a state of things was established, more or less analogous to that which geography now presents to us. It was necessary, in a word, that the "dry land should appear."

Extensive observation on the condition of the crust of the earth proves that such forms were not assumed definitely and permanently at once, but that they underwent a long succession of changes, in the course of which the outlines of land and water were frequently varied: what was land at one time became the bottom of the ocean at another, and what was the bottom of the ocean at one time, rising to the surface, assumed the forms of continents and islands at another.

It would be easy to show, by an analysis of the effects produced by such a succession of catastrophes, that they all tended to one definite end; namely, the final adaptation of the earth for the dwelling-place of the human race, and its contemporaneous tribes.

After the superficial temperature had fallen sufficiently low to allow of the deposition of water upon the surface, and the formation of an universal ocean, a series of convulsions commenced, each of which was produced by the agency of the matter in igneous fusion contained within the solid shell of the earth. This matter acting unequally against the inner surface of the shell cracked it from time to time, producing fissures, through which the igneous pasty matter issued, cooling and solidifying when exposed to the external atmosphere. Each convulsion necessarily changed the relative levels of different parts of the solid surface, and this was attended with a corresponding change in the distribution of the waters of the ocean. Upon the occurrence of each phenomenon, these waters would rush with furious impetuosity over such parts of the land as would fall to a lower level, while at other places the solid bottom of the ocean would rise above the surface of the waters, forming new continents and islands. Such catastrophes must not be regarded as either conjectural or imaginary. They have, on the contrary, left on the earth visible traces by which their occurrence has not only been demonstrated, but even their dates have been geologically ascertained, so that we are enabled to state the order in which they occurred.

189. For a long period of time, during which these catastrophes were developed at intervals, the superficial temperature depended infinitely more upon the internal heat transmitted to the surface through the crust, than upon the effects of solar radiation. It must be remembered, that, so far as the superficial temperature would depend upon the heat received from the interior through the crust, the temperature would be everywhere the same. Thus it would affect the poles and the equator equally, and would be equally diffused over all latitudes; but, on the contrary, so far as the temperature would depend on solar radiation, it would vary with the latitude, as it does at present, being greatest between the tropics, and least

within the polar circles. But, as has been just observed, during the early periods of the history of the earth, to which we now refer, the influence of internal heat predominating enormously over that of solar radiation, the effects of the latter were wholly effaced, and, consequently, the superficial temperature was uniform at all latitudes.

190. For a long period after the commencement of superficial solidification, this temperature was far above the limit compatible with the existence of any form of organic life, animal or vegetable; and, consequently, during this interval the globe was a mere waste, unanimated by life and unadorned by vegetation. Meanwhile, nevertheless, a succession of changes took place, the effects of which have remained so visibly traced upon the earth to the present day, that geologists have been enabled to pronounce not only their existence but their order. Four times the solid crust was cracked, and the internal fluid matter issued through the fissures, forming four systems of mountain-ranges, which still exist to attest these remarkable facts in the primitive history of our planet.

191. At length the temperature being reduced to a point compatible with organised life, creative power began to be manifested. The earth was peopled with animals and clothed with vegetation, but these animals and this vegetation differed altogether from those which now animate and cover the globe. They were, however, adapted by divine wisdom to the then condition of the earth, the temperature being not only greater than any which prevails at present, but, as has been stated, uniform at all latitudes.

192. After this, a like succession of convulsions took place, long intervals of time intervening, by each of which the relative levels of the land were changed, and consequently the distribution of the waters of the ocean completely altered. Such changes implied universal inundations, which involved the destruction of all animated nature, animal as well as vegetable. In short, a succession of deluges must have attended such convulsions, each deluge destroying all the tribes of animals and plants which existed on the globe at the time of the catastrophe.

193. After each of these convulsions, the waters at first turbid, and holding in suspension great quantities of matter washed away and eroded from the former land, as well as enormous quantities of the remains of the animals and plants previously existing, would, after a time, become tranquil, and then a process of vast importance to the preservation of the history of the globe would take place. The organic remains of animals and plants suspended in the waters would be deposited at the bottom

of the ocean, and over them would subside also the solid matter sustained in a state of comminution in the waters. The remains would thus be buried in strata sensibly horizontal, and, being covered up by the earthy and mineral matter which would subside from the waters, they would be protected from the destructive action of air and water thereafter, and would thus be preserved to future generations as records of the past history of the earth.

In the interval of tranquillity following each such deluge, creative power was again brought into operation, and the earth was repeopled with animated creatures, and reclothed with vegetation; but in all cases the animals and plants composing the new kingdoms of nature, though agreeing with those recently destroyed in their classes and generic characters, differed from them altogether in their species. In short, a new kingdom of nature was produced, but constructed upon the same general principles.

194. By researches made in the crust of the earth, and careful analyses of the constitution of its strata and of the animal remains contained in them, geologists have ascertained, with a high degree of probability, if not with absolute moral certainty, that subsequently to the first appearance of the forms of animal life, which, as has been stated, took place after the fourth great convulsion of the globe, there were at least twenty-eight successive convulsions of a like nature, each of which was attended with the complete destruction of the animals and plants which existed upon the globe, their remains being buried in the manner already stated under the sedimentary deposits made by the new oceans which followed the crisis.

The actual occurrence of these several convulsions, and of the existence of the successive animal and vegetable kingdoms, differing one from another in the species of which they were constituted, has been proved by geologists by two species of evidence, one depending on the condition of the stratification, by which it has been shown that many of these catastrophes were attended with the elevation of systems of mountains which still exist upon the surface of the earth, while others, though not indicated by mountain ranges, are rendered evident by certain discordances and disturbances in the state of the strata. These catastrophes have also been indicated by the discovery of the buried remains of each of the several animal and vegetable kingdoms here mentioned.

195. In fine, after the latest of the catastrophes, when the last strata of the tertiary formation were deposited, the most recent exertion of creative power took place, and the globe was peopled with the tribes which now inhabit it, including the human race.

Such is a brief and rapid sketch of the phenomena which form the subject of the pre-Adamite history of the globe, which it is our present purpose briefly to sketch.

196. The manner in which the geological age of mountain-ranges is determined by the state of the strata observed upon their slopes has been already explained, but this is so important an element in our present inquiry, that it may be useful to recapitulate it and present it to our readers under another aspect.

When we see anywhere the sedimentary strata composing the crust of the earth inclined, we can pronounce with certainty that they have been disturbed from their original position which was horizontal, and that, in short, an elevation has taken place by a force acting from beneath. So far as relates to the strata thus inclined, the epoch of the catastrophes would be undetermined, but if at the foot of the mountains we find other strata *a b c*, fig. 112,

Fig. 112.

Fig. 113.

horizontal, it becomes evident that the elevation of the former must have taken place before the deposition of the lowest of the latter, since the latter are in the position in which they naturally subsided from the waters.

The geological date of the elevation in this case would be between the period of the strata, which are elevated and inclined, and the lowest, *a*, of the horizontal strata. In the case of all mountain-ranges, data of this kind, determining the geological epochs of the disruption which produced them, are supplied. In some places we see for example the stratum *a*, heaved upwards, and *b* horizontal, fig. 113. In such cases the date of the catastrophe is posterior to the deposition of *a*, and anterior to that of *b*.

Fig. 114.

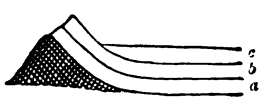
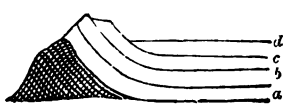


Fig. 115.



In other cases, both *a* and *b*, fig. 114, are uplifted and inclined, but *c* is horizontal, and it is accordingly inferred, that the date

of the catastrophe was between the deposition of the strata and *c*.

In like manner if it be found that while the strata *a*, *b*, and *c* are all uplifted and inclined, *d* is horizontal, fig. 115, it is inferred that the date of the catastrophe was between the periods of the deposition of *d* and *c*, and so on.

It will be evident that we have here assumed that the strata *a*, *b*, *c*, *d*, &c. are in the natural succession of strata, in the order of geological time, found in any complete section of the earth's crust, in which no strata are deficient.

197. It must also be observed that the direction of the inclination of the strata thus uplifted, corresponds with and determines the direction of the ridge of mountains upon the flanks of which they lie, and it has resulted from the extensive and profound researches of M. Elie de Beaumont, that the chains of mountains in general whose directions are parallel have the same geological date, as is proved by the strata inclined upon their sides and horizontal at their base. Mountain ranges, therefore, which until the discovery of this important law were regarded as geologically distinct and independent, are now brought into the same system. Each mountain system, therefore, must be regarded not as a single chain, but as a number of parallel chains which may be near or distant from each other within any assignable limits. It may also be observed, that the parts even of the same chain are not always continuous, but may be broken by intervals along which, as it were, the crust sinks to the level of the surrounding plain.

198. The systems of mountains which have thus been grouped according to their geological dates have usually received denominations from some remarkable locality in which their prevalence is most conspicuous. Thus one is called the system of the Pyrenees, another the system of the principal Alps, another the system of the western Alps, and so on.

The different convulsions which have taken place upon the surface of the globe, and which have produced the several mountain systems, seem to have been always sudden. In effect at some distance from the place where the discordance of the stratification manifests former convulsions, the same strata are found concordant and horizontal, from whence it follows, that in such cases the sedimentary deposition has not been suspended, the disturbance of the crust has been local, and the interval during which it has prevailed has necessarily been short.

199. During each successive geological period, the earth has been differently divided into land and water, the continents and islands of one period being submerged during another, and the

parts submerged becoming dry land. During each period the deposition of strata corresponding to it, has been of course confined to such parts of the earth only as were covered by water, and hence we are able to trace the geographical limits of sea and land, by tracing the limits of the deposits characteristic of each stratum.

Thus, during the Silurian period, the Silurian strata have been deposited only on those parts of the globe which were during that period covered by water, but not on those which formed the land. When we use the expression, therefore, the *Silurian sea*, we must be understood to mean that portion of the globe which, during the Silurian period, was covered by water, and those portions must necessarily be co-extensive with and limited by Silurian deposits. In the same manner during the Cretaceous period, the globe, as before, consisting of land and water, the cretaceous deposit was made only in those parts which were then covered by water, and formed the bottom of what is called the *Cretaceous sea;* the other parts of the earth, which at that epoch formed the land, being consequently destitute of the cretaceous strata.

In the same sense is to be understood the expressions, the *Triassic sea*, *Jurassic sea*, *Tertiary sea*, and so on.

The absence, therefore, of any particular deposit in an extent more or less considerable of the crust of the earth, indicates that the subjacent deposit was above the level of the sea, and formed an island or continent more or less elevated during the period in which the absent deposit was made. Thus, for example, an extensive plateau in the centre of France must have been dry land from the most remote geological epochs; and at the epoch of the formation of the deposit which constitutes the present Paris basin, the greatest part of Europe must have been dry land, while Paris and a large tract surrounding it, as well as Bordeaux and the surrounding regions, were covered by the sea, as will be more fully explained hereafter.

But it happens also that the parts which thus prove to have been dry land at a certain geological epoch, have been afterwards covered by more modern sediments; from whence it follows that they must have subsequently sunk beneath the ocean, so as to receive these new deposits. It is by such subsidences of the land that some of the geological convulsions, whose traces will be hereafter noticed, have been explained.

200. According to the results obtained from the researches of M. Elie de Beaumont, it appears from a comparison of the various mountain ranges of Europe, and from an examination of the strata upon their slopes and at their bases, that since the solidifi-

cation of its crust this part of the globe has undergone at least seventeen distinct convulsions, each of which has produced a mountain system, the mean direction of which has been ascertained, and is characteristic of it. These seventeen systems have received denominations, as already mentioned, from some localities in which their prevalence is most conspicuous, and the directions which characterise them are indicated in the following diagram.

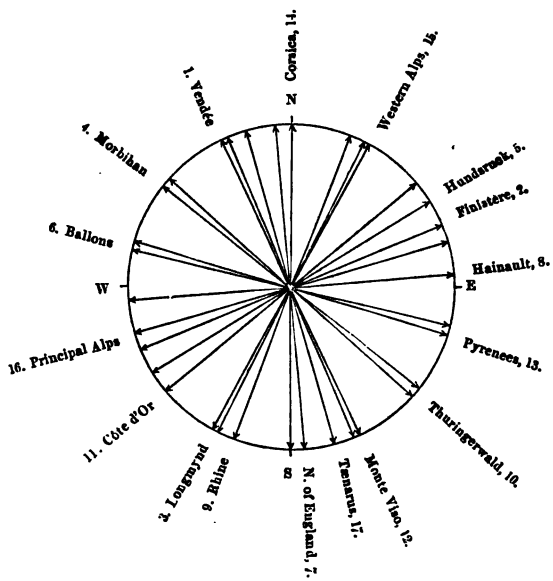


Fig. 116.—Directions of the principal Mountain-systems.

201. The order in which these several systems have been elevated is indicated by the numbers placed at one extremity of the lines indicating their direction, and these directions are expressed with more numerical precision in the following table, where W. 21° S. means a point 21° south of west; N. 23° E., a point 23° east of north; W. 38° N., a point 38° north of west, and so on. The places indicated in the second column are those from which the system takes its name, and those indi-

cated on the fourth column those at which its direction has been determined.

1st	Vendée . . .	N. N. W.	Vannes.
2nd	Finistère . . .	W. 21° S.	Brest.
3rd	Longmynd . . .	N. 23° E.	Vannes.
4th	Morbihan . . .	W. 38° N.	Vannes.
5th	Hundsruck . . .	W. 31° S.	Bingerloch.
6th	Ballons	W. 15° N.	Ballons.
7th	North of England . .	N. 5° W.	North of England.
8th	Hainault . . .	W. 5° S.	Netherlands.
9th	Rhine	N. 21° E.	Upper Rhine.
10th	Thuringerwald . .	W. 40° N.	Thuringerwald.
11th	Côte d'Or . . .	W. 40° S.	Côte d'Or.
12th	Monte Viso . . .	N. N. W.	Monte Viso.
13th	Pyrenees . . .	W. 18° N.	Pyrenees.
14th	Corsica	N.	
15th	Western Alps . .	N. 26° E.	Alps of Dauphiné.
16th	Principal Alps . .	W. 16° S.	Alps of the Valais.
17th	Tænarus	. . .	Greece.

202. In laying down upon the map the directions of the several systems, their divisions into such as run between N.W. and S.E., and between N.E. and S.W., becomes very apparent, as will appear by reference to fig. 117, in which the several systems are indicated by peculiar marks as follows:—

1. —o o— Vendée.
2. — — — Finistère.
3. —·—·— Longmynd.
4. o o—c c Morbihan.
5. Hundsruck.
6. Ballons.
7. ..... North of England.
8. Hainault.
9. Rhine.
10. Thuringerwald.
11. Côte-d'Or.
12. Monte Viso.
13. Pyrenées.
14. Corsica.
15. Western Alps.
16. Principal Alps.
17. Tænarus.

203. The systems directed between the N.W. and S.E. run from the Rhine towards Provence and Brittany, and those between the N.E. and S.W. from Normandy, Brittany, and the Pyrenees towards the Apennines.

204. The geological dates of these several systems of elevation, determined, as will presently appear by the position of the strata on their flanks and at their bases, are as follows:—

I. System of Vendée raised before the deposition of the Cumbrian group.

II. System of Finistère raised between the Cumbrian and the green slate of Longmynd.

III. System of Longmynd raised between the Longmynd slate and the Bala limestone.
IV. System of Morbihan raised between Bala limestone and the Silurian deposit.
V. System of Hundsruck raised between the Silurian and Devonian.
VI. System of Ballons raised between the Devonian and carboniferous.
VII. System of North of England raised between the carboniferous and Permian.
VIII. System of Hainault raised between the Permian and Vosges sandstone.
IX. System of Rhine raised between the Vosges sandstone and Triassic.
X. System of Thuringerwald raised between the Triassic and Jurassic.
XI. System of Côte d'Or raised between the Jurassic and lower cretaceous.
XII. System of Monte Viso raised between the lower and upper Cretaceous.
XIII. System of Pyrenees raised between the upper Cretaceous and lower Tertiary.

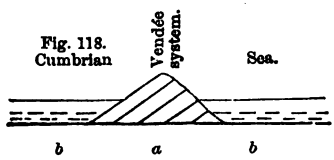
Fig. 117.—Map of France, showing the prevailing direction of the principal systems of mountains.

XIV. System of Corsica raised between the lower and middle Tertiary.
XV. System of Western Alps raised between the middle and upper Tertiary.
XVI. System of principal Alps raised between the upper Tertiary and Diluvial.
XVII. System of Tænarus raised between the Diluvial and Alluvial.

205. We shall now briefly explain the stratigraphical characters by which these several dates have been ascertained.

I. SYSTEM OF VENDÉE.—In the earlier researches of M. Elie de Beaumont, the Hundsruck system, the elevation of which appeared to precede immediately the Silurian period, was assumed to be the earliest catastrophe of that kind of which the crust of the earth afforded any evidence. Observations more multiplied and exact, and a more elaborate discussion of the phenomena, discovered by his own labours and those of other geologists, have, however, conducted him to the conclusion that four of the existing mountain systems were produced at much earlier epochs.

The first of these, to which the French province of La Vendée has given its name, is represented with the Cumbrian beds horizontal at its base, in the section fig. 118, where *a* represents the mountain range, and *b* the Cumbrian deposit.

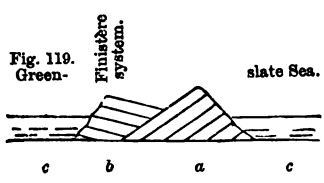


We may therefore imagine *b* to be the sea of the epoch, which succeeded this elevation, in the bottom of which the Cumbrian formation was deposited. It is in this sense that the *Cumbrian sea* is to be understood, and a like form of expression will be used in a corresponding sense in other cases.

The date of the catastrophe by which the Vendée system was pushed up, must therefore be prior to the deposition of the Cumbrian strata.

This mountain system has hitherto been but little studied. Traces of it are shown by M. de Beaumont to exist in schists of Belle-Isle, of the embouchure of the river Villeine, in the mica-schists or gneiss on the banks of the river Blavet (dep. Morbihan), in Beaupréau, and Bourbon-Vendée.

206. II. SYSTEM OF FINISTÈRE.—By the catastrophe which produced this system, the Cumbrian formation *b*, fig. 119, was uplifted, and in the period of tranquillity which followed, the waters deposited the strata of green slate of Longmynd in Wales. These last, *c*, are accordingly seen in horizontal strata along the base of the system.

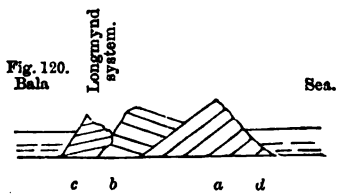


The date of the catastrophe is therefore posterior to the deposition of the Cumbrian formation, and anterior to that of the green slate of Longmynd and Westmoreland.

Traces of this system exist in the gneiss and mica-schists of Brest, the Cumbrian schists between Pontivy and Falaise, the chloritic schists of Cherbourg, the Cumberland ranges, and at Gotheburg and Upsal in Sweden, whence it is continued into the southern part of Finland. It is also seen in the Pyrenees and in Catalonia.

207. III. SYSTEM OF LONGMYND.—The green slate deposits were forced up and inclined by this convulsion, and in the tranquil period which ensued, the Bala lime-stone beds, *d*, fig. 120, were deposited by the ocean on their flanks, where these strata are still seen in the same horizontal position.

Fig. 120.



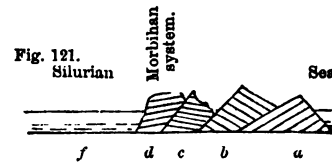
The date of the catastrophe is therefore posterior to the lime-stone.

In Brittany the green slate does not appear between the Bala limestone *d* and the Cumbrian strata *b*, which shows that that part of Europe was dry land while the Bala sea was making its deposits.

The stratification due to the Longmynd system has been traced in Limousin in France, in the mountains of Morocco, in the Serra da Estrella in Portugal, in the Erzgebirge in Saxony, in the gneiss mountains of Moravia, and of those parts of Bohemia bordering on Austria, on the north-east of the Wenner lake in Sweden, along the coast of the Gulf of Bothnia in Finland, and along that of Wiborg on the other side.

208. IV. SYSTEM OF MORBIHAN.—The convulsion which produced this system upheaved the Bala formation *d*, fig. 121, throwing its strata, previously horizontal, into an inclined position. In the tranquil period which ensued, the mountains thus formed were washed by an ocean and seas in which were deposited the Silurian formation *f*, which is still horizontal, on the flanks of this system.

Fig. 121.



This convulsion, therefore, immediately preceded the Silurian period, and was posterior to the deposition of the Bala limestone.

The system of Morbihan is very extensive; it is traced in the mica-schists and gneiss of the Loire Inférieure, in the islands which terminate the south-west coast of Brittany, in the granitic plateau which extends along that coast beyond Parthenay, and over part

of the Limousin, where traces of it appear between Tulle and Nontron. It is found also in the north-eastern part of Brittany and in the Bocage of Normandy. Traces of it are found in the mica-schists and gneiss of Messina, in the Erzgebirge, in Bœhmerwaldgebirge, in the granitic steppes which extend from Volhynia towards the Don, in Labrador and in Canada.

209. V. SYSTEM OF HUNDSRUCK.—The catastrophe which produced this system coincided with the commencement of animal and vegetable life upon the earth. The strata deposited by the waters of the Silurian sea which preceded it, were uplifted from their horizontal position so as to form the mountain ranges to which M. Elie de Beaumont has given the name of *Hundsruck*, from a mountainous region of Germany extending over the southern part of Rhenish Prussia and Rhenish Bavaria, where it is connected with the chain of the Vosges. Its geological date is fixed by the fact that the Devonian strata are found in a horizontal position upon its flank, as shown in fig. 122. The catastrophe must, therefore, have followed the Silurian, and preceded the Devonian period.

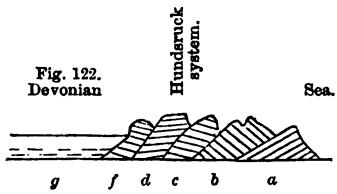


Fig. 122.

This system is traced through France, in Brittany, in the department of the Ille-et-Vilain, in the strata which cover Cape Finistère, in Mayenne, and in the department of the Orne and the Manche. It appears also in the slate formation of the Ardennes, of the Eiffel, in the mountains of Hundsruck and the Taurus. It is also found in the Hartz mountains, in the Erzgebirge, in Bohemia, in the island of Gothland, in Finland and Lapland. In England it is traced in Cornwall, Westmoreland, and the Grampians.

210. VI. SYSTEM OF THE BALLONS.—This system originated in a convulsion by which the Devonian strata, *g*, were uplifted and thrown into an inclined position, as shown in fig. 123. The waters of the globe, when tranquillity ensued, deposited the carboniferous beds in horizontal strata, *h*, in the bottom of seas, oceans, and lakes, the latter being at more elevated levels than the former, as shown in the figure.

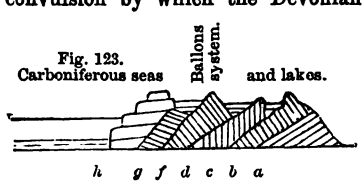


Fig. 123.

The date of the catastrophe is, therefore, antecedent to the carboniferous, and posterior to the Devonian period. This system is

traced in France in the anthracite schistous beds on the banks of the Loire and of the Brest canal. It is also seen in the department of Mayenne, in the south-east of Laval, in the southern part of the Vosges, in the chains of Lozère, Margeride, and the Corrèze.

In England the system is directed from Cornwall to the Grampians, in Belgium from Avesnes to Liège, and in Germany in the Hartz mountains, which probably have received from it their peculiar form.

It may also be traced in Bohemia, Saxony, Sweden, Russia, Siberia, in the Altaï range, in North America, along the line of the Alleghanies, and in southern Asia.

211. VII. SYSTEM OF THE NORTH OF ENGLAND.—The convulsion which produced this system dislocated the coal formation, *h*, fig. 124, and in the tranquil period which succeeded the waters of the ocean deposited the Permian strata, *i*.

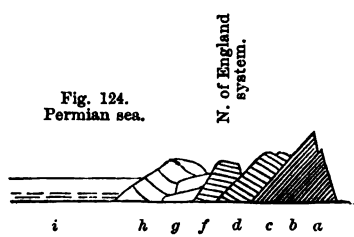


Fig. 124.
Permian sea.

Its date, therefore, was prior to the Permian and subsequent to the carboniferous period. This system is characterised by lines of summit which extend from the parallel of Derby to the frontiers of Scotland, through Yorkshire, and between Cumberland and Northumberland. Traces of it are also found in the neighbourhood of Bristol, as well as in the south of Ireland. It is traced also both in Norway and Sweden, upon the crests of the southern chains.

212. VIII. SYSTEM OF HAINAULT.—The catastrophe which produced this system has been manifested less by any elevated ridges than by a series of dislocations and compressions which are seen in England, between Pembrokeshire and Mansfield, and which also traverse the Netherlands, running nearly east and west. All the existing strata, and particularly the coal measures, *h*, fig. 125, and the Permian strata, *i*, exhibit these effects. The strata of Vosgian sandstone are, however, undisturbed and horizontal as they were deposited from the waters, showing that the date of this catastrophe was anterior to their deposition and posterior to the Permian period. These positions of the Vosgian strata are apparent at Sarrebruck.

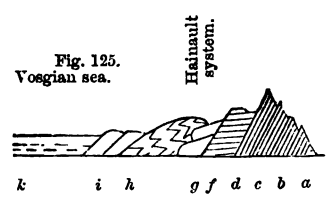


Fig. 125.
Vosgian sea.

Traces of this system are found between Liege and Lille, in the direction of certain granitic islets, in the coal basin of Brittany, and from Laval towards Quimper.

213. IX. SYSTEM OF THE RHINE.—This system is manifested chiefly upon the cliffs of the Rhine, between Bale and Mentz, with various other parallel escarpments, indicating faults which have affected all the strata, including the Vosgian sandstone, *k*, fig. 126, patches of which they have pushed up to different heights, without disturbing their horizontal position. Hence have resulted islands in the seas of this epoch, around which the Triassic group has been deposited at a lower level, as shown in fig. 126.

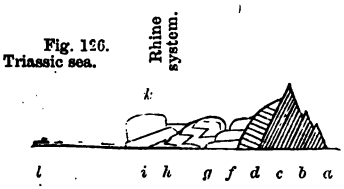


Fig. 126. Triassic sea.

214. X. SYSTEM OF THURINGERWALD.—The mountains to which this system has given its name, and of which the Bœmherwaldgebirge is the continuation, constitute the natural frontiers which divide Bavaria, Saxony, and Bohemia. The most remarkable effects of this catastrophe are manifested between Cassel and Linz, where the Triassic strata, *l*, are uplifted and overlaid by the Jurassic deposits, *m*, in level strata, fig. 127.

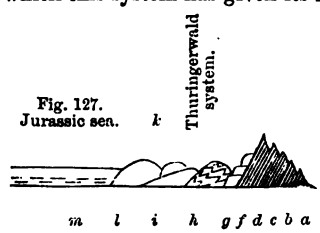


Fig. 127. Jurassic sea.

Some traces of this system are seen in the south-western part of the Vosges, where the Triassic strata (*grès bigarré*) are raised considerably above the general level, an effect probably produced by the masses of serpentine which protrude in that region. Between Avallon and Autun some granitic islets and dislocated Triassic strata have also the north-west direction, and are surrounded by the Jurassic limestone in level strata. The date of the catastrophe is, therefore, anterior to the Jurassic period, but posterior to the Triassic.

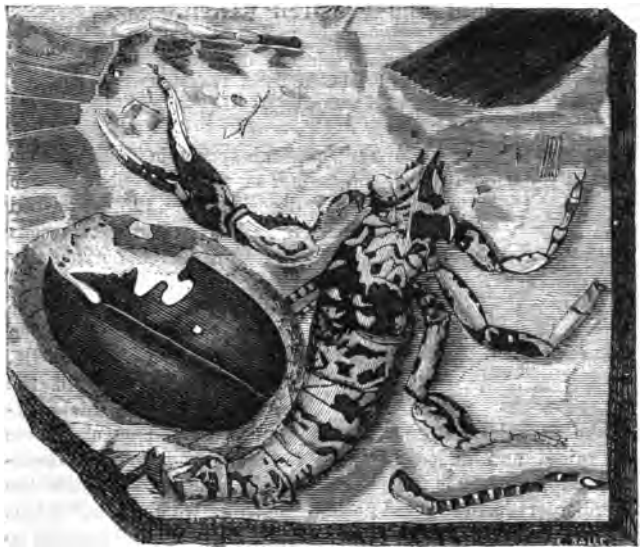


Fig. 143.—FOSSIL SCORPION (CYCLOPHTHALMUS BUCKLANDII).

THE PRE-ADAMITE EARTH.

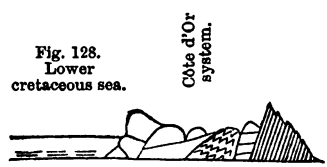
CHAPTER II.

215. Elie de Beaumont's mountain systems continued: System of Côte d'Or. —216. System of Monte Viso.—217. System of the Pyrenees.—218. System of Corsica.—219. System of the Western Alps.—220. System of the Principal Alps.—221. System of Tænarus.—222. Principal effects of this convulsion.—223. Extension of De Beaumont's system by analogy to the remainder of the globe; general plan of mountain systems.—224. Geological horizon explained; mineralogical characters insufficient to identify it.—225. Indications supplied by fossiliferous deposits.—226. Twenty-nine fossiliferous strata.—227. Zoological stratification.—228. Method of determining outlines of land and water twofold: mineralogical and zoological.—229. The mineralogical tests uncertain.—230. The zoological tests clear and definite.—231. Organic remains which characterise the bottom of deep seas.—232. Organic remains which determine the shores of seas.—233. Others which determine the bottoms of shallow seas.—234. Others which indicate the embouchures of rivers and estuaries.—235. Conventional terms.—236. Successive creations.—237. Geological periods and stages.—238. Six great formations.—239. Resolution of the earth's crust into 29 stages. —240. Six geological ages.—241. Succession of geological periods.—

242. Zoological terms: four principal divisions of animals.—243. Subordinate nomenclature.—244. Table of the classes of animals.—245. Zoological characters of the principal divisions.

215. XI. System of Côte d'Or.—This system in its direction is nearly at right angles to the preceding, see fig. 116. The Jurassic deposits, *m*, fig. 128, are pushed up, and the lower cretaceous strata, *n*, ranged horizontally upon them, as shown in fig. 128. This system may be traced without interruption from Luxembourg to Rochelle, and in all the crests of the Jura. It was by this catastrophe that the eastern border of the central plateau of France was raised and dislocated after the formation of the Jurassic group, which is there considerably elevated; while the other borders have suffered no derangement: which indicates that this plateau, in the chief part of its extent, has undergone no change since the Jurassic period. Traces of this catastrophe are also manifested in several other parts of France—north and south; in several parts of Germany; and especially in the Erzgebirge, which, though divested of the Jurassic limestone, has the lower cretaceous strata in horizontal beds at its foot.

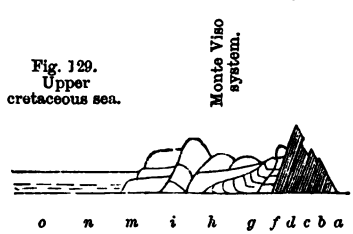
Fig. 128. Lower cretaceous sea.



The date of this catastrophe is, therefore, between the period of the deposition of the lower cretaceous strata and that of the Jurassic group.

216. XII. System of Monte Viso.—The dislocation of the lower cretaceous deposits, *n*, fig. 129, by this catastrophe, and the presence of the upper cretaceous deposits in their horizontal position, are distinctly manifested in the Alps of Dauphiné, showing that the date of the catastrophe is between the periods at which the upper and lower cretaceous deposits were made.

Fig. 129. Upper cretaceous sea.



The upper cretaceous strata, represented by beds of nummulites, and sometimes, but very rarely, by grey and compact limestone, are alone found to be horizontal, as may be seen on the Col de Bayard and the Col Maurin. Indications of this system may also be traced at the south of Grenoble, in the north of Dauphiné,

in the mountains which connect the Alps with the Jura, as far as the Pont d'Ain and Lons-le-Saulnier. It was this catastrophe which determined the principal direction of the coasts of Italy, as well as that of a system of elevated ridges in Greece, of which Pindarus forms part.

217. XIII. SYSTEM OF THE PYRENEES.—By this catastrophe the upper cretaceous strata, *o*, fig. 130, were raised and dislocated.

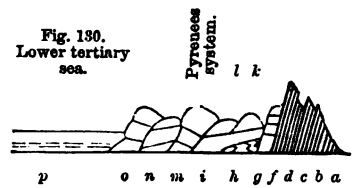


Fig. 130.
Lower tertiary sea.

The lower tertiary strata, *p*, being horizontal, show that the date of the catastrophe is between that of the lower tertiary and the upper cretaceous periods. By this disturbance the upper cretaceous strata have been elevated to a considerable height, forming lofty cliffs, especially along the Spanish frontier.

The calcareous strata of the Paris basin, usually considered as the lowest of the tertiary strata, having but little extent over the surface of France, or even of Europe, it follows that at the epoch of the formation of the Pyrenean system, the chief part of the continent of Europe was suddenly raised above the waters and rendered dry land.

Not only the whole chain of the Pyrenees, as well in France as in the Asturias, belongs to this epoch, but also that of the Apennines, the Julian Alps, the Carpathians, the Balkans, and the mountains of Greece. The same direction is discovered in numerous dislocations and denudations in Germany, in the north of France, and in the Wealden of England; from whence it appears that this catastrophe must have had a vast extent, affecting certainly the entire surface of Europe and probably of the world.

218. XIV. SYSTEM OF CORSICA.—This catastrophe, unlike the former ones, is not marked by an elevation of the strata, which were formed under the water. After the preceding elevation, the Parisian lime-stone, which would then be found, is completely absent in those places where the new catastrophe was manifested.

The absence of this deposit signifies that the ground over the whole of Europe at that epoch was raised above the level of the sea; but as observation shows us that in this same place other marine deposits were made at a later period, it must be concluded that those parts which were first elevated above the ocean sunk below it at a subsequent period, so as to receive the superjacent deposits now found upon them. This must in fact have happened to part of the Paris basin, to Touraine, the chief part of Gascony,

all Switzerland, the valley of the Rhone from Lyons to the sea, as well as to several parts of Italy, Corsica, and Sardinia, which, not exhibiting any of the Parisian deposits, must have been brought above the level of the waters by the Pyrenean elevation, which produced the thirteenth system, and must have afterwards sunk to receive the subsequent deposits.

The Corsican system is manifested also by elevations and dismemberments, which have given their ultimate form to the mountains, which rising between the valleys of the Saone, the Loire, and the Allier, have directions from north to south. In these countries all the secondary strata are disturbed, and around them are formed the fresh-water deposits of Auvergne and the Loire. It was along the direction of this disturbance that were subsequently placed all the volcanic cones of the chain of the Puys.

Traces of this Corsican system are found in the mountains which connect the Alps with the Jura, in spite of the dismemberments which the succeeding catastrophes produced. There exists also a great number of chains having the same direction in the eastern and southern parts of Europe, in Tuscany, the Papal States, Istria, Albania, Greece, and so on. The islands of Corsica and Sardinia are also arranged from north to south, and present along the coast tertiary deposits in horizontal strata of the same age as those which are found in all the parts of France above mentioned.

219. XV. System of Western Alps.—If the Swiss Alps and those of Savoy and Dauphiné present traces of catastrophes which took place since the elevation of the system of Côte d'Or, it is not less evident that the actual profile of the chain has a date much more recent. In fact the middle strata of the tertiary system, which were only raised above the waters after the date of the Corsican system, are now elevated sometimes to vast altitudes, as well as the Jurassic and cretaceous formations beneath them. The only strata found horizontal are the upper tertiary. Thus it follows that this chain of mountains, which includes the most lofty in Europe, were not raised to their present elevation from the common level of the continent until after the deposition of the middle tertiary strata.

The matter which broke through the crust of the earth in this catastrophe, was the particular species of granite of which Mont Blanc and Monte Rosa are formed. A multitude of granitic islands in different parts of the continent are also formed of it, on the flanks of which appear inclined the tertiary, cretaceous, and Jurassic strata. These granites at an early epoch in the progress of the science, when the principles which determine the

dates of mountain ranges were less understood, being regarded as dating from the earliest geological periods, received the name of *Protogyne*. It is now known, however, that they did not break through the terrestrial crust until after the deposition of the middle tertiary system, seen in the strata around the Paris basin.

The relative position of the strata, determined by the elevation of the Western Alps, is illustrated in fig. 131, where the same letters are used to indicate the several strata, as in the former figures. The sea, which subsequently deposited in horizontal strata the upper tertiary system, is indicated in the figure.

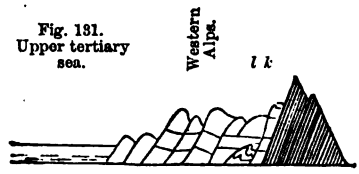


Fig. 131.

This catastrophe produced not only the lofty chains of Savoy and Dauphiné, but extended its influence over Europe north and south. On the one side Nova Zembla and the whole Scandinavian Peninsula were affected by it, and on the other it produced a series of dislocations which are seen from Narbonne to Catalonia, determining the position of the whole Mediterranean coast of Spain. Its influence was felt south of the Mediterranean, producing the mountains of Morocco as well as those of the regency of Tunis.

220. XVI. System of principal Alps.—This catastrophe has produced the grandest features of relief upon the European continent. The lacustrine deposits, formed after the elevation of the Western Alps, were themselves dislocated by it, and along the foot of the chain there are no other horizontal strata than the diluvial deposits of the present epoch. The matter pressed up from the inner regions of the globe by this catastrophe were the different varieties of melaphyres, the sienites, the euphotides and serpentines, which forced up all the tertiary deposits of Piedmont and Provence, as well as the granitic rocks which constitute the most elevated summits of the principal chains of the Alps.

Not only were all the mountains which extend from the Valais and St. Gothard into Austria raised on this occasion, but the greater part of the surface of Europe shared in the movement. In fact the surface of the continent was lifted into a gentle acclivity, directed towards the line of summit of this great chain. It is thus for example that the plains of Bavaria rise slowly in a direction a little east of south, and those of Lombardy in an opposite direction. In the south of France, in like manner, the tertiary formation rises from the south towards the north, from

the borders of the Mediterranean to Saint-Vallier, and on the other side the inclination is in the opposite direction. From the borders of the Loire the surface rises gently on the one side in the direction N.N.W., and on the other in the direction S.S.E., as far as the valleys of Auvergne. At the foot of the Pyrenees, the ophites, as well as the gypsums and the saliferous masses connected with them, form a tract whose direction is parallel to the chain of the principal Alps, and resemble the arrangement of the serpentines of the valley of Aosta.

221. XVII. SYSTEM OF TÆNARUS.—This is the last and most recent great catastrophe of which Europe has been the theatre. It took place at an epoch when our seas were peopled by the tribes which now inhabit them, and when possibly the human race had already appeared, so that the result might not inaptly be called the *post-Adamite system.*

After the diluvial deposits which surrounded the principal Alps in horizontal strata had been made, the surface of Tuscany underwent a dislocation parallel to a great circle, directed nearly N.W. and S.E. The deposits raised at this epoch include nothing but shells, similar to those of the existing seas, as may be shown by an examination of the tufa of the Phlegræan fields, a district on the shore of the Bay of Baiæ, near Naples, and of the Somma of the island of Ischia. The sedimentary deposits of Sardinia, where M. de la Marmora discovered the remains of infant arts, appear also to have shared in this movement, which must therefore have been one of extremely modern date compared with all those already described.

222. It is to this catastrophe that must be ascribed the elevation of the Somma, of Stromboli, and of Etna, all of which would have been totally deranged if they had existed before the catastrophe of the principal Alps, by which so many ravages have been produced in all directions. To the same movement are probably also due the volcanic formation of Auvergne and the Vivarais, the ejections from which have issued from fractures and fissures produced by some of the antecedent catastrophes.

The system of elevation, the traces of which are seen in Provence, near Nice, in Sardinia, in Sicily, and in the Phlegræan fields, is parallel to the modern system, which Messrs. Boblaye and Virlet have indicated at the southern part of the Morea, and which they have called *Tænarus*, from the adjacent cape of that name.

223. Such then, according to the remarkably able and perspicuous analysis of M. Elie de Beaumont, is the history of the principal changes which the surface of the globe has undergone

from the first consolidation of its external crust to the present epoch. Since it has been found in Europe (the only part of the world which has hitherto undergone sufficiently accurate geological survey), that the various ridges which have the same or parallel directions belong to the same epoch of elevation, analogy would justify a similar inference respecting all parts of the globe, and we should naturally conclude that parallel lines of direction and contemporaneity of formation are interchangeable principles. It is at least interesting to examine from this point of view the principal chains which are known in different parts of the earth.

To show how far the results of these observations in Europe may be generalised by such analogies, M. Elie de Beaumont designed for M. Beudant the plan which, by their permission, we have reproduced in fig. 132, showing the generalisation of the classification of mountain systems according to their dates, as above explained.

It will be seen upon this chart that the direction of the system of the Pyrenees extends from the Alleghanies in North America to the Indian Peninsula by the Carpathians, Mount Caucasus, the mountains of Persia, and the Ghauts in India. To the south of this line there are several parallel ridges, such as those which run from Cape Ortegal in the Asturias to Cape Creux in Catalonia. Also the little range of Grenada, the mountains which surround the southern side of the desert of Sahara, intersecting the direction of the Atlas, and, in fine, the Apennines, the Julian Alps, and the mountains of Croatia and Roumelia, extending to those of the Morea.

The system of the Ballons, so closely related in direction to that of the Pyrenees, is also represented in the Alleghanies.

The direction of the system of the Western Alps is observed from Morocco to New Zealand, passing along the eastern coast of Spain, the south of France, and a great part of the Scandinavian peninsula. Parallel ridges are found in the Cordilleras of Brazil, in the regency of Tunis, in Sicily, at the point of Italy, and in Asia Minor. All the littoral range of the old continent, from the northern cape of Lapland to Cape Blanco in Africa, partakes of this direction.

The direction of the principal Alps is in accordance with numerous other ridges. Chains parallel to this direction are found in the Atlas, in Spain, and across the old continent to the China Sea, including Mount Olympus, the Balkans, the Taurus, the central chain of the Caucasus between the Black Sea and the Caspian; in the long series of mountains which extend through Persia and Cabul, including the Parapamisan mountains in Afghanistan and eastern Persia, the range of the Hindoo Koosh,

Fig. 132.—Plan showing the direction of the principal mountain systems according to the classification of M. Elie de Beaumont.

and, in fine, the Himalayas, which include the most lofty mountains in the world.

Parallel to the Corsican system are the chains of Syria and Palestine. Parallel to that of Monte Viso, those of Pindus. Parallel to the Thuringenwald are the mountains of Attica and Negropont. Parallel to the Côte d'Or, or perhaps the Hundsruck, are the Altaï range, and so on.

224. In all that has been hitherto explained the mineralogical components of the succession of strata are the only indications which have been given to determine each geological horizon,—a term to be understood as indicating that layer of the crust extending generally over the whole globe, which was contemporaneously deposited. If the waters of the oceans and seas of each epoch deposited everywhere a stratum composed of the same materials, and if the waters of no epoch anterior or posterior deposited like strata, then the mineralogical character of each stratum would supply certain indications of its date. But this has not been the case: on the contrary, strata which were incontestably deposited at the same epoch, are often composed in different places of different mineralogical constituents, while, on the other hand, strata of different epochs of deposition are sometimes found to consist of the same mineralogical components. Although, therefore, in a certain general sense, the mineralogical character of the strata, as has been explained, indicates the date of its deposition, yet when we come to define more exactly the successive geological horizons, these mineral characters cease to afford the necessary tests.

225. The indications which the mineralogical constituents of the strata have thus failed to supply, have happily been obtained from their fossiliferous deposits. From extensive observations, made both in the old and new world, it has been ascertained that in descending from stratum to stratum downwards, a succession of layers of organic remains have been found lodged within definite limits of geological level, the species found in each being almost totally distinct from those found in those above and below it. So that wherever we find the same organic remains, however different the strata in which they are lodged may be in their mineralogical character, we may conclude with certainty that they are of contemporaneous deposition.

226. Each fossiliferous stratum is distinguished from those above and below it, not only by the specific characters of its organic remains but also by its stratigraphic position, and, as we shall presently show, there are clear indications that the deposition of each such stratum, followed the destruction of the organic world by one of those violent convulsions which have been already described. Of these distinct fossiliferous strata twenty-nine

have been enumerated and connected with indications of as many geological convulsions, the result of each of which was the complete destruction of animal and vegetable life upon the globe, the fossil deposits of the next strata of the series in ascending, being the remains of the animal and vegetable tribes which re-peopled and re-clothed the earth after the ensuing period of tranquillity.

227. The organic remains, deposited in the successive layers of the terrestrial crust, show the character of the animal and vegetable world during the periods of tranquillity which followed the several convulsions which thus devastated the globe. It is, however, a problem of not less high interest to determine the geographical character of the surface, as defined by the relative extent and outlines of land and water, during each of these periods. The solution of this problem would be attended with no difficulty, if we possessed a perfect knowledge of the condition of the sedimentary strata in all parts of the earth. But not to mention our want of all knowledge of the state of that large portion of the earth's surface, which is at present covered with water, we have as yet been able to effect only a very limited and imperfect survey even of that lesser part which forms the land. Nevertheless, the positive knowledge, small as it is, which the labours and researches of geologists have supplied, aided by obvious analogies on which conclusions are based, having, if not in all cases moral certainty, at least a high degree of probability, has afforded a close approximation to the series of geographical changes which that part of the earth, at present composing the land, has undergone since the earliest geological epochs.

228. The means whereby the outlines of land and water at any proposed geological period are determined are twofold, one method depending on the mineralogical character of the strata, and the other upon that of its organic deposits.

To explain these methods, let us suppose, for example, that it is required to determine the outlines of land and water, upon those parts of the globe of which we possess sufficient geological knowledge, during the Silurian epoch. The first point will be, in that case, to determine the extent and limits of that class of strata to which the name Silurian has been given. Let us imagine that all the strata of more modern date are removed, and the Silurian strata laid bare. These strata were deposited during the Silurian period at the bottom of the seas and oceans which then partially covered the globe, and whose outlines and limits are the immediate subject of inquiry. The land during this period consisted of those parts of the globe alone upon which the Silurian deposit was *not made*. If, therefore, we possess the means of discovering the exact extent and outline of the Silurian deposit, we possess

all that is necessary for the solution of the proposed question. The outlines of this deposit are, in fact, identical with the outlines of land and water during the Silurian period. The land consisted, of course, of those strata which, being more ancient than the Silurian, were pushed above the level of the waters by the convulsion which preceded the period of tranquillity during which the Silurian strata were deposited.

229. If, therefore, the extent and limits of the Silurian deposit could be certainly and definitely ascertained, the problem would be solved; but independently of the knowledge, more or less imperfect, which direct observation has supplied as to the extent and limits of this deposit, some uncertainty attends the identification of the various strata to which the name Silurian is properly given, by their mere mineralogical characters. It has been already explained, that strata of simultaneous deposition vary in their mineralogical characters from place to place, those which have been deposited in one part of the world consisting of mineral constituents wholly different from those which have been deposited at the same epoch elsewhere.

230. The doubt which this raises, however, has been removed by the light thrown upon geology by fossil zoology and botany. If the mineralogical characters of contemporaneous strata be doubtful, there can be no uncertainty as to the zoological character of their fossil contents.

Although it be true that many of the genera of animals and plants, deposited in strata of different dates are common, this is not the case with the species which, with very rare exceptions, are peculiar to each period. If, therefore, the observer, guided merely by the mineralogical character of the strata under examination, be uncertain as to its date, his doubts will disappear upon a due examination of its organic deposits. No other than the strata of one particular epoch can contain the same combination of species of animals and plants.

231. But the aid afforded by the organic deposits is not limited merely to the determination of the date of the strata. They also supply the means of determining, with much greater precision than can be obtained from the mere mineralogical constituents, the outlines of land and water. It is known that certain genera of animals can live only in the tranquil bottoms of deep seas; there they live and there they die, and there their remains are buried in the strata deposited by such waters. Where such remains, therefore, are found in the strata of the crust of the earth, such strata must have been at the epoch of its deposition at the bottom of a deep sea or ocean.

232. The bodies of certain animals when dead and not dis-

membered, will float upon water. The remains of such would necessarily be washed upon the shore, and cast upon the coasts between high and low water-mark. There, upon the successive returns of the tide, they would be gradually covered with sand or mud, and would thus be buried in the strata to become future fossils. Where such remains are found, therefore, the strata must have been upon the very limits of land and water, upon the strand or coast surrounding continents or islands. If the floating bodies of such animals be dismembered, either by incidental fracture or by the voracious attacks of other living animals, their dismembered parts being, bulk for bulk, heavier than water, would sink, and in such cases would be deposited at the bottom of the sea. It must, therefore, be expected that such dismembered remains would be sometimes found in the fossil state, in juxtaposition with the complete remains of animals which live exclusively in the bottoms of deep seas; and such, in fact, is found to be the case. But from these indications, rightly understood, no doubt can arise, since in no case is the entire body of such an animal found in such a position.

233. Other marine animals live not on the very coasts of the sea, nor yet in very deep waters, but frequent the littoral parts of seas and oceans, and in the bottom of these their remains are accordingly found.

Without going, with any degree of tedious minuteness, into the zoological characteristics of the several marine tribes, it will, therefore, be understood, that the deposition of the complete remains of certain species can only take place on the coasts of seas and oceans between high and low water-mark, the deposition of others on the littoral parts, and of others again in the bottoms of deep seas.

Thus, according to the varying zoological characteristics of the organic remains, the geologist is enabled to pronounce in a definite manner upon the outlines of land and water.

234. The bodies of dead animals and uprooted vegetables are carried by the currents of rivers to their embouchures, and are there deposited, mixed with certain species of marine animals. Thus, the combination of fresh-water shells, land animals, and plants, with the remains of marine animals, are the sure indications of the embouchures of rivers and estuaries.

235. Having explained the indications by which the outlines of sea and land and the animal and vegetable kingdoms corresponding to them at each epoch of geological time can be determined, with more or less approximation, we shall proceed to relate the history of the earth, from the first appearance of animated nature upon it to the present epoch. It will, however, be convenient

previously to fix the sense of certain conventional terms necessary to be used in such a narrative, by which the effects of the succession of terrestrial convulsions, and the intervals of geological time will be expressed.

236. As has been already stated, the earth we inhabit has undergone a long series of convulsions, affecting its entire surface, each of which has been succeeded by a long interval of tranquillity, during which, the waters, in a state of equilibrium and quiescence, deposited the solid matter suspended in them in a series of layers, and in each of these intervals the author of nature called into existence an animal and vegetable kingdom, resembling more or less the present.

237. The intervals of time which elapsed thus between convulsion and convulsion, we shall call *geological periods*, and the mineral strata deposited by the waters during such periods, we shall call *geological stages*.

Unlike historic, geological time is therefore not measured by years and centuries. Its units are much more vast. Each of them is a *period*, that is an interval of time, whose exact length is unascertained, but which must be considered as having an analogy, more or less close, to the interval which will have elapsed between the creation of the present animal kingdom and the epoch, whenever it may arrive, at which, it, like all those which preexisted, shall be swept away.

238. An analysis of the strata composing the crust of the earth has presented certain features, upon which geologists have founded a classification of the stages just mentioned. According to this classification, the stages, from the igneous rocks to the latest deposits, which immediately preceded the appearance of the present state of things, have been resolved into six groups, denominated as follows:—

1. Azoic formation.
2. Palæozoic formation.
3. Triassic formation.
4. Jurassic formation.
5. Cretaceous formation.
6. Tertiary formation.

239. The Azoic formation consists of groups of strata, the lowest of which reposes upon the igneous rocks. The Palæozoic formation rests upon the uppermost strata of the Azoic group, and in it, as its name implies, are found the first traces of organic life. The general stratigraphic characters of the other groups may be seen by reference to the tabular sections of the Earth's Crust, given in § 47.

The Palæozoic formation consists of five distinct stages, each

containing its own peculiar organic deposits. In like manner, the Triassic formation consists of two such stages, the Jurassic of ten, the Cretaceous of seven, and, in fine, the Tertiary of five; so that the whole fossiliferous portion of the earth's crust may be considered as consisting of twenty-nine stages, each stage being a catacomb in which the remains of the preceding creation are buried.

240. The intervals of time during which each of these six formations were deposited, we shall call *geological ages*. Thus, that in which the Azoic formation was deposited we shall call the *Azoic age*, that in which the Palæozoic formation was deposited we shall call the *Palæozoic age*, and so on.

241. The lesser intervals during which the several *stages* composing each geological *formation* were deposited, and during which, as already stated, an animated world was created, lived, and was destroyed, we shall call *geological periods*. Thus the Palæozoic *age* consisted of five *periods*, denominated in their numerical order, from the earliest or lowest to the latest or uppermost, the *first Palæozoic period*, the *second Palæozoic period*, and so on. In the same manner, the Triassic *age* consisted of two *periods*, the *first* and the *second*. The Jurassic of ten counted from the lowest, or most ancient, to the highest or most modern, and the like of the other formations.

242. Since it will be necessary to make frequent reference to the various forms of animal life, which from period to period prevailed upon the earth; and such references must occasionally necessitate the use of certain technical zoological terms, it will be convenient for those readers who are not already familiar with the elements of zoology, to give a general outline of the classification of animals which we shall adopt.

Naturalists have classed all the various forms of animal life into four primary divisions, denominated from their peculiar structure: 1. VERTEBRATA; 2. ANNULATA; 3. MOLLUSCA; and 4. RADIATA.*

243. Each of these primary divisions is resolved into a certain number of CLASSES; each class is again resolved into a certain number of ORDERS; each order is resolved into a certain number of GENERA;† each genus is resolved into a certain number of SPECIES, and each species consists of certain VARIETIES.

Here the classification terminates, the varieties being composed of individuals. Thus, if it be required to determine the zoological character of any individual animal, it is first necessary to state

* Much confusion prevails among the classifications adopted by naturalists; we shall, however, generally adhere to that of Cuvier.

† By an intermediate step, the orders are sometimes first grouped in *families*, and the families subdivided into *genera*.

the *variety* to which it belongs, then the *species* of which this is a variety, then the *genus* of the species, then the *order* of the genus, then the *class* of the order, and, in fine, the great primary division to which this class belongs.

244. The four primary divisions above mentioned are resolved into classes, as follows:—The *Vertebrata* into *four*, the *Annulata* into *six*, the *Mollusca* into *five*, and the *Radiata* into *five*, making altogether twenty classes, as shown in the following table.

CLASSIFATION OF ANIMALS.

	CLASSES.	EXAMPLES.
VERTEBRATA.	Mammifers	Man, ass, dog, horse, whale.
	Birds	Eagle, sparrow, cock, ostrich, duck.
	Reptiles	Tortoise, lizard, snake, frog.
	Fishes	Perch, carp, eel, skate, shark.
ANNULATA.	Insects	Bee, grasshopper, flea, butterfly.
	Myriapods	Scolopendra, Iulus. Figs. 133, 134.
	Arachnides	Spider, scorpion, mite.
	Crustacea	Crab, lobster, shrimp.
	Cirrhipeds	Anatifa (animals which attach themselves to ships' bottoms.) Fig. 135.
	Annelides	Earth-worm, leech.
MOLLUSCA.	Cephalopods	Octopus, cuttle-fish, nautilus. Figs. 9,
	Gastropods	Snail, whelk. [10, 11, p. 62.
	Lamellibranchia (acephala).	Oyster, mussel.
	Brachiopods	Lingula, terebratula, pentamerus. Figs. 18, 19, p. 66.
	Bryozoa	Reticulipora. Figs. 20 to 23, p. 67.
RADIATA.	Echinodermata	Star-fish, sea-urchin. Fig. 136.
	Polyparia, or Zoophytes	Coral, astrea. Fig. 137.
	Foraminifera	Figs. 104, 105, 106.
	Amorphozoa	Sponges, fungi. Figs. 138, 139, 140.
	Infusoria	Fig. 107.

245. The Vertebrate division is characterised by an internal skeleton and a cerebro-spinal nervous system. It takes its name from the vertebral or spinal column, to which all the subordinate parts of the skeleton are attached.

The Annulata have no internal skeleton, but in its stead a tegumentary covering, composed of movable rings, which gives them their characteristic form. Their nervous system consists of two long cords running longitudinally through the abdomen, twisted at intervals into knots called *ganglions*. The tegumentary covering, which is always annular, is sometimes hard and calcareous, as in the lobster and shrimp, and sometimes soft, as in the earth-worm and leech.

The Mollusca have neither internal skeleton nor articulated envelope. Their bodies are sometimes naked, but often protected by a shell.

The Radiata, including the lowest forms of organic life, is a group consisting of classes so heterogeneous, that many naturalists, not following Cuvier, have differently resolved them. They have in general no articulated skeleton, either internal or external, and scarcely exhibit the rudiments of a nervous system. Those to which the name Radiata is more properly applied are composed of organs disposed radially around a centre or axis.

Some naturalists have given to this division the name of ZOOPHYTES, from a Greek word, signifying the link between animals and vegetables; while others have confined this latter term to the Polyparia.

Fig. 182.—ILLUSTRATION OF THE ANIMAL AND VEGETABLE KINGDOMS DURING THE TERTIARY AGE.

a. Palæotherium magnum. *c*. Anoplotherium commune.
b. Palæotherium minus. *d*. Crocodile.

THE PRE-ADAMITE EARTH.

CHAPTER III.

246. Derivations of the names.—247. Examples of the classes.—248. Number of fossil species.—249. Their distribution in 29 stages.—250. These stages correspond to 29 periods.—251. Successive manifestations of creative power.—252. First creation of organised beings.—253. General view of the series of catastrophes.—254. **The Palæozoic age**: Murchison's section of the corresponding stages.—255. How these are manifested in different parts of the world.—256. Stratigraphical evidence of the distinction of the stages.—257. Five stages of the Palæozoic formation.—258. Vegetable kingdom of the Palæozoic age.—259. FIRST PALÆOZOIC PERIOD.—260. Extent and limits of the seas.—261. Character of the Fauna.—262. Of the Flora.—263. Tropical climate universal.—264. No terrestrial animals.—265. Inhabitants of the seas.—266. Synopsis of the animal kingdom.—267. Examples.—268. Duration of this period.—269. SECOND PALÆOZOIC PERIOD.—270. Synopsis of the animal kingdom.—271. Genera created and revived.—272. General character of the animal and vegetable kingdoms.—273. Outlines of land and water.—274. Elie de Beaumont's Silurian map of Western Europe.—THIRD PALÆOZOIC PERIOD: 275. Mineral character of the strata.—276. Table of the Fauna.—277. Mollusca and Radiata.—278. Outlines of land and water.—279. Extent of the seas.—FOURTH PALÆOZOIC PERIOD: 280. Table of the fauna.—281. Fossil crustacea.—282. Mollusca and Radiata.

246. SINCE the technical names of several of the classes into which the principal divisions are resolved will not be familiar to some of the readers of this tract, it may be useful to indicate the origins from which they are severally derived.

Mammifers is from a Latin word, signifying the bearers of breasts or paps, and consequently is applicable to animals which suckle their young.

Reptile comes from the Latin word *repto*, I creep or crawl.

Insects are so called from a Latin word, signifying the division of its body into segments.

Myriapods is a Greek word, signifying thousands of feet, figs. 133, 134.

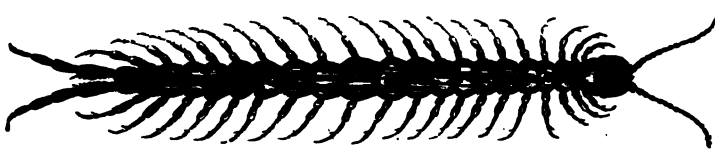


Fig. 133.—The Scolopendra.—Example of the class Myriapods.

Arachnida is taken from a Greek word, (ἀράχνη, arachné,) signifying a spider's web.

Crustacea is taken from a Latin word (*crusta*), signifying a hard covering or crust.

Cirrhipeds, or Cirrhopods as it is sometimes written, take their

Fig. 134.—The Iulus. Example of the class Myriapods.

name from a Latin word (*cirrhus*), signifying hair, the compound signifying hair-footed animals; that is, whose members of locomotion are hairs, fig. 135.

Annelides, as well as Annulata, is taken from a Latin word (*annulus*), signifying a *ring*.

Cephalopods is a Greek compound, signifying *head-footed*, or animals whose organs of locomotion are upon their heads, figs. 9, 10, 11.

Gastropods is likewise a Greek compound, signifying *belly-*

footed, or animals whose organs of locomotion are attached to their bellies.

Lamellibranchia is compounded of two Latin words, (*lamella*, a

Fig. 135.—The Anatifa (animals which attach themselves to ships' bottoms). Example of the class Cirrhipeds.

plate or *leaf;* and *branchia*, a *gill*,) the class including those animals which have gills or branchia placed by pairs along the body, of a lamellated form.

Acephala is also a Greek compound, signifying *absence of head.*

Brachiopods is a Greek compound, signifying *arm-footed*, or animals whose members of prehension are also those of locomotion, figs. 18, 19, § 71.

Bryozoa, from the Greek word *βρύον*, a mossy sea-weed, figs. 20 to 23, § 73.

Echinodermata is a Greek compound, signifying *spiny-skinned*, fig. 136.

Polyparia is another Greek compound, signifying produced by polypes or corals, fig. 137.

Foraminifera is a Latin compound, implying the existence of foramina, or openings in the partitions of the shells, figs. 100 to 106.

Amorphozoa is a Greek compound, signifying living things *destitute of definite form*, figs. 138, 139, 140.

Infusoria is a Latin name, implying the existence of this class of animals in vegetable and other infusions, fig. 107..

247. Since many of the names of the genera and species of animals and plants would be unintelligible to a large portion of

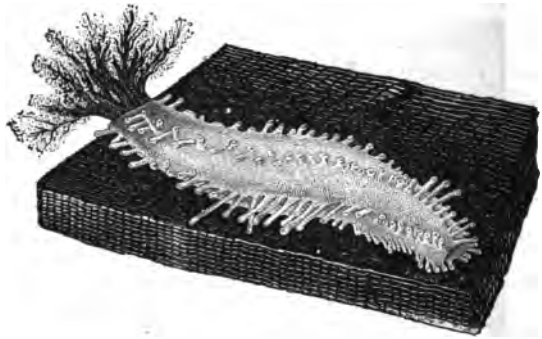


Fig. 136.—The Holothuria. Example of the class Echinodermata.

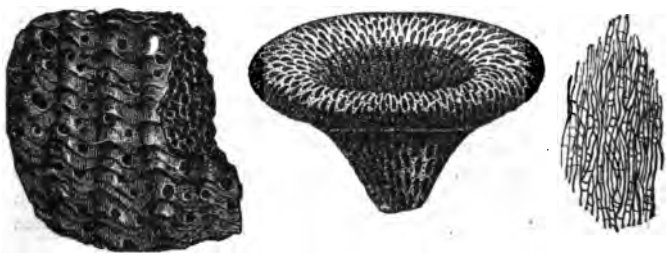
our readers, while a full explanation of them would be incompatible with the objects and limits of the present tract, we shall generally adopt the expedient of giving a specific example of each

Fig. 137.—Polypes of the genus Asteroides. Example of the class Polyparia.

in a parenthesis after its technical name. In many cases, however, even this mode of illustration is not possible, since none of the species or genera of certain orders are familiar objects, and in many cases those which we shall have to mention have ceased to

exist, so that no analogous example can be found among the living classes. In such cases we shall endeavour, as often as convenient, to accompany the technical name with a figured

Fig. 138. Fig. 139. Fig. 140.



Examples of Amorphozoa.
Fig. 138.—Cliona Duvernoyi (fossil). Fig. 139.—Cribrospongia reticulata.
Fig. 140.—A part magnified.

representation of some species of the object. In the preceding table we have accordingly given some familiar examples, and we now annex figured illustrations of those objects which may be supposed to be the least familiar to ordinary readers. The references to the figures are given in the table.*

248. Geologists have ascertained the existence of the organic remains of about twenty-four thousand species of the different orders of animals, which they have assigned to upwards of fourteen hundred and seventy genera. Of these numerous species none survive; but we find in the existing animal kingdom about five hundred and fifty of the genera, the remainder being extinct.

249. Until very recently, it was considered by geologists that those twenty-four thousand fossil species were distributed through the strata of the crust of the earth, in such a manner that the great majority of them should be common to strata of very different dates of deposition, and that comparatively few were exclusively found in strata of a particular date; these few being consequently called *characteristic species*, inasmuch as they supplied to geologists certain tests, by which the dates of strata left uncertain from their mineralogical character could be fixed. The elaborate researches of M. D'Orbigny, who has catalogued,

* We must warn the reader that he must not understand that the example given in the parenthesis is in every case an individual of the species, or even of the genus, of the object to be illustrated. It will be more generally a specimen of the class or order. This is the only expedient that I can devise to popularise this part of our subject.

described, and located on the earth's crust, above eighteen thousand species of Mollusca and Radiata alone, have demonstrated that all the species found in strata of the same date, with extremely rare exceptions, are characteristic of these strata, being found there exclusively, and in no other strata of anterior or posterior deposition; so that, instead of a few species only being characteristic, it would appear that all the species are so, with exceptions so rare as to be altogether insignificant.

It appears, therefore, that on the crust of the earth there is a sort of organic stratification, consisting of a series of superposed layers of animal remains, each of which contains a distinct collection of species, no two such layers having any species in common, save in very rare and exceptional cases, and that even these exceptions may be satisfactorily explained as arising from accidental causes.

250. Since twenty-nine such organic stages have been determined, it must be inferred that during the geological period corresponding to each of them, the earth was peopled by a collection of animals which had no previous or subsequent existence, and which constituted a distinct and independent creation. This inference is fully confirmed by the fact, that on comparing stage with stage, we do not find the successive faunas passing one into the other by slow and imperceptible degrees; but, on the contrary, we find between those of every two successive stages, a distinct and unmistakeable line of separation. In the superior layers of each stage, the fauna peculiar to it totally disappears, as though it were annihilated by some universally destructive agency; and it is not until we arrive at the lowest or first layer of the succeeding stage, that the next fauna appears not gradually and successively, but suddenly and simultaneously over the whole extent of the globe, so far as geological observation has extended, and everywhere, from the equator to the poles, the same species are found in it.

251. Hereupon two questions necessarily arise: What are the physical causes which produced the total destruction of the fauna of the inferior stage, and the creation of that of the superior? To the former a satisfactory answer is obtained, as we shall presently show, by the geological convulsions, the devastating effects of which have been already frequently noticed in these pages. But when we seek the agency which twenty-nine times successively called into existence a new animal kingdom to replace that which was previously destroyed, we are compelled to acknowledge the limits of our intellectual powers, and to prostrate ourselves in reverence before that Omnipotence to whose agency alone these great creative acts can be assigned. There are limits which the human

mind cannot overleap, circumstances before which the march of intellectual research must be arrested, and ultimate facts which must be admitted without any human power of explaining them.

252. When the temperature of the earth had cooled down to a point compatible with the maintenance of organised life, and its crust had thickened so as to give it comparative stability and permanence, it pleased the Omnipotent to call into existence the animal and vegetable kingdom, that continued to live upon the earth during the Cambrian period, and was destroyed by the convulsion which closed that period, the remains of the species composing it being deposited in its strata.

253. After this complete destruction of animal and vegetable life a period of repose ensued, after which the same Almighty Power at the commencement of the second Palæozoic or Silurian period, called into existence another and different animal kingdom; different, at least, so far as regarded species, many of the genera being common to that of the previous period. The close of the Silurian period was signalised by a like catastrophe, this second animal kingdom being similarly swept away and the earth again left unpeopled and destitute of vegetation. Another period of repose ensued, after which, at the commencement of the third Palæozoic or Devonian period, a third animal and vegetable kingdom was called into existence, and continued upon the earth during the Devonian period, at the close of which, in like manner, another destruction ensued, followed by another creation at the commencement of the fourth Palæozoic or Carboniferous period, and so on destruction following destruction, and creation following creation, during all the succeeding periods to that which immediately preceded the human epoch. The latest or fifth Tertiary period terminated like the others in a convulsion which swept from the earth all animal and vegetable life existing upon it, burying the remains in the highest layers of its crust. After a final period of repose, the present animal kingdom, including the human race, were called into existence, and the world as we see it commenced.

The Palæozoic Age.

254. The Palæozoic formation, whether it be examined in reference to its mineralogical strata or the organic remains deposited in it, is resolved into five distinct stages. The researches of Murchison in England and Russia, those of M. D'Orbigny in South America, those of several eminent geologists in the United States, and the observations of M. de Verneuil in France, all concur in establishing this division.

The stratification from the superior limit of the Azoic rocks upon which the Palæozoic formation rests, to the upper limit of the Carboniferous stage, delineated in section by Sir R. Murchison, is shown in fig. 141, as it is presented on the surface of the earth in strata variously inclined. The five divisions into which the whole formation is resolved are denominated, proceeding from the lowest upwards, the Cambrian (sometimes called the Lower Silurian), the Silurian, the Devonian, the Carboniferous, and the Permian.

Fig. 141.

255. In the geological map of England by Sir R. Murchison, the stages succeed each other regularly throughout Wales and the western parts of England, where they appear in some places in concordant, and in others in discordant, stratification. They are traced scarcely less distinctly in Germany. The same regular succession of five superposed stages is seen in Russia and in Sweden from west to east, and extending in the same order to Central Russia. Along the slopes of the Ural, the stages being tilted upwards, are found, as may be expected, in a contrary order, the lowest being the most eastward, and the uppermost the most westward. M. D'Orbigny found the same regularity in South America.

256. The complete distinction of the stages, and the geological evidence of the convulsions by which they were rendered separate and independent, are found in the fact that in some places particular stages are absent. Thus we see in the United States the three first stages only existing in concordant stratification for hundreds of leagues, the lowest being absent. The same is observable in the department of Sarthe and the Manche in France. Elsewhere the Carboniferous and Devonian stages alone are found; as, for example, in the Pas de Calais, and in certain parts of Spain, or one only of them, as in Norway, Sweden, Russia, France, and some other countries.

257. Upon a general view of the Palæozoic formation and its component stages, there is evidence, founded on the indications which

have been already explained, that during each of the five successive periods the earth consisted, as at present, of continents and seas; that the continents were clothed with vegetation; that the seas were peopled by various marine tribes, some living at parts of great depth, some near the coasts, and others upon the shores between high and low water-mark; and that even the crust of the earth was subject to the same gradual oscillations which are observed to exist at present in the north of Europe and in other parts of the globe.

258. The existence of a vegetable kingdom in each of the five Palæozoic periods is proved by the presence of coal in all the stages. That mineral is worked in Portugal in the Silurian stage. In Spain its richest mines are in the Devonian stage, and in Saxony it is worked in the Permian stage. These facts show, that though the coal-fields are by far most prevalent in the Carboniferous, the other Palæozoic stages furnish their share of that mineral to industry and the arts.

Having thus taken a general view of the Palæozoic age, considering its periods collectively, we shall now briefly notice the most remarkable circumstances attending these periods severally.

FIRST PALÆOZOIC PERIOD.

259. The first Palæozoic stage includes the group of strata of which the Cambrian system of Sedgwick and the lower Silurian system of Murchison are composed. It appears from an examination of the strata, more especially those observed in North and South America and Bohemia, that a considerable time must have elapsed between the epoch at which this stage began to be deposited on the subjacent Azoic rocks, and the commencement of the animalisation of the globe. Strata of immense thickness are everywhere found between the superior surface of the Azoic rocks and the first layers of organic remains, the formation of which, according to all the known laws of sedimentary deposits, must have occupied a great lapse of time. That these were deposited from waters which had a temperature too elevated to allow of organic life, is in the highest degree probable; and it must be inferred that the creation of an animal and vegetable kingdom, or a fauna and flora, as they are called, was postponed until the temperature of the globe had fallen to a point not much above that of the present tropics.

260. During this first Palæozoic or Cambrian period the waters of the ocean covered all that part of Europe extending from Spain to the Ural mountains, as well as a great part of North and South America. The shores of these seas can be traced, by the

means already explained, in the strata of England, Sweden, and Russia, and in those of the State of New York. The organic deposits show that, like the present seas, they were inhabited by the various classes of marine animals which are peculiar, some to shores within the play of the tides, others to littoral regions more removed, and others to the great depths of the ocean.

261. The only Vertebrate animals of this period which have left their traces are some placoid fishes, which belong to the family of Cestracions, of which the shark presents a living example. Of articulated animals there lived a great number of Trilobites (fig. 6, § 62), an order which at a period a little later became extinct. The forms of life, however, which most abounded belonged to the Molluscous and Radiated divisions. Tentaculiferous cephalopods swarmed in the seas, the genera of some of which did not survive the period, and those of many disappeared before the close of the Palæozoic age.

Molluscous brachiopods, marine gastropods, lamellibranchia (oyster and mussel), and bryozoa, existed in numbers more or less considerable.

Of the Radiata there prevailed echinodermata, asteroids, and numerous crinoids, a great number of polyparia or zoophytes, and some amorphozoa.

262. The remains of vegetation consist chiefly of some marine plants peculiar to the State of New York, described and figured by Mr. Hall. Coal of this epoch, which can only consist of vegetable remains, is worked at Vallongo in Portugal.

The remains of vegetation, as well as the visual organs of animals, show that light and air existed then as now. We have already noticed the structure of the eyes of Trilobites, and shown their analogy to those of insects and other Annulata.

263. It is certain, that not only at this first period, but at all succeeding periods, until that which immediately preceded the present creation, the heat proceeding from the interior predominated over the influence of solar radiation, in a sufficient degree to efface all isothermal lines, and to equalise the climate at all latitudes from the equator to the poles. Proofs of this will appear in the analysis of the fauna and flora of all the stages, since the same tropical genera and families will be found deposited in the strata at the line and within the polar circle, as well as at all intermediate latitudes.

264. In this first period no terrestrial animals existed, although the land was clothed with a luxurious vegetation; at least no remains of such are found. The perishable nature of the insects, and many other Annulata, might have caused their disappearance; but, notwithstanding this, traces of such tribes are found in later

deposits, and it is probable that if land Vertebrates had existed, remains of them would be found.

265. The seas, however, abounded with life, including animals of all the principal divisions, Vertebrata, Annulata, Mollusca, and Radiata.

In the following table we have given the genera of the animal kingdom during this period, exclusive of the Annulata.

266. *Synopsis of the Animal Kingdom (exclusive of the Annulata) in the First Palæozoic Period.*

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	1	1			
Mollusca.	Cephalopods	12	12	0	2	2
	Gastropods	12	12	0	0	0
	Lamellibranchia	11	11	0	1	1
	Brachiopods	14	14	0	4	4
	Bryozoa	8	8	0	3	3
Radiata.	Echinodermata	11	11	0	5	5
	Polyparia	7	7	0	3	3
	Foraminifera	0	0	0	0	0
	Amorphozoa	2	2	0	1	1
		78	78	0	19	19

267. Eighteen genera of Trilobites existed in the first Palæozoic period, of which seven never re-appeared in any future period, and are consequently characteristic of the Cambrian stage. Some individual examples of other Annulata have been found, one of the most remarkable of which is the Nereites Cambriensis, fig. 5, § 36. The number of species of the Mollusca and Radiata alone, exclusive of the other divisions, which are ascertained to have lived in this period, is 426. These have been catalogued and described by M. d'Orbigny.*

268. The duration of this first world of animal and vegetable life may be estimated with some degree of approximation by the thickness of the deposits produced in its seas, which has been found in many places so much as 13000 feet.

Its close is marked by the discordances of stratification which prevail between the Cambrian and the Silurian strata, and it is probable that the convulsion by which it was terminated, was that which raised the Morbihan system of mountains of M. Elie de Beaumont (208).

* Prodrome de Paléontologie, vol. i. p. 1—26.

SECOND PALÆOZOIC PERIOD.

269. The convulsion which closed the preceding period was succeeded by an interval of tranquillity of greater or less duration; after which, it pleased the Omnipotent, by a second great act of creation, to clothe the land with vegetation, and re-people the earth.

270. In the following table we have given, as in the former case, a synopsis of the generic forms of this new creation.

Synopsis of the Animal Kingdom (exclusive of the Annulata) in the Second Palæozoic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	8	7	1	0	0
Mollusca.	Cephalopods	11	2	9	3	0
	Gastropods	10	2	8	0	0
	Lamellibranchia	8	2	6	0	0
	Brachiopods	17	7	10	1	0
	Bryozoa	10	5	5	1	1
Radiata.	Echinodermata	15	12	3	3	6
	Polyparia	20	16	4	3	3
	Foraminifera	0	0	0	0	0
	Amorphozoa	1	0	1	0	0
		100	53	47	16	.10

As before, the only important traces of the Annulata of this period which remain, are the Trilobites, of which nineteen genera have been found. Of these, eleven are identical with genera which existed in the previous period, and eight are new.

The total number of species of Mollusca and Radiata which have been ascertained to have existed in this period is 418, which have been described and catalogued.*

271. The only class of Vertebrates yet created were fishes, of which eight genera existed in this period, all of the placoid family (shark). One of these had existed in the previous period, the other seven being new.

272. The remains of the vegetation consist of some genera of marine plants, found in the state of New York, and figured by Mr. Hall. That the continents generally were covered with vegetation is proved by the traces of coal found in this stage at St. Sauveur.

As in the former period, the animal remains are analogous to

* Prodrome, p. 27—35.

those of the tropics at present, and were uniformly distributed over all latitudes to which geological observations have been extended, from the line to latitude 69°, from which it is inferred, that during this period the temperature of the earth was everywhere tropical, and everywhere uniform.

273. The outlines of land and water were not materially different from those of the first period. It is probable, however, that the seas retired from a portion of the central part of Brittany, and advanced eastward, as well in Wales as in Cumberland, leaving in the west a larger portion of uncovered land. They extended, probably without interruption, from Europe to America, covered a great part of North and South America, as well as all that part of Europe which extended from Spain to the line of direction now occupied by the Ural mountains.

274. An examination of the Silurian strata has enabled M. Elie de Beaumont to trace an approximate sketch of the outlines of land and water in Western Europe, from which the map given in fig. 142 was drawn.

It appears from this, that there existed at this time two granitic tracts, one between Brest and St. Malo, and the other between Brest and Poitiers; the former having the direction of the Finistère, and the latter of the Morbihan system, a neck of land connecting them having the direction of the Longmynd system. These probably, therefore, owed their elevation to the three convulsions which produced these ranges severally. Other tracts of land existed in Cornwall, in Scotland, and in Sweden, as shown in the map, having the direction of the systems of Finistère and Longmynd. The granitic plateaux which include the Limousin and Auvergne were also then above the waters, and were connected with a much larger tract, extending from Toulon to Innspruck. This second Palæozoic period appears to have been terminated by the effects of the geological disruption which produced the Hundsruck system of M. Elie de Beaumont (209).

THIRD PALÆOZOIC PERIOD.

275. After an interval of tranquillity as before—the land being divided from the waters—the earth was repeopled with new tribes and clothed with new vegetation. The strata deposited during this third palæozoic period have been denominated by Sir R. Murchison, Devonian, from the circumstance of their prevalence in that county. The principal mineralogical characteristic of the Devonian stage is the old red sandstone.

276. The animal world, now called into life, consisted, so far as

appears by its organic remains of 156 genera (exclusive of the Annulata), of which 75 were new and 81 revived, having existed in the former periods. It appears from the following table that in this period the vertebrate animals were still limited to fishes, but their number was considerably increased, having consisted of only 8 genera in the preceding period, and of 26 in the present. This period was also signalised by the first appearance of reptiles, of which, however, one genus only, called the *Sauropterus*, was

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Third Palæozoic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	1	1	0	0	0
	Fishes	26	26	0	13	13
Mollusca.	Cephalopods	13	5	8	6	2
	Gastropods	22	9	13	1	0
	Lamellibranchia	18	7	11	0	0
	Brachiopods	20	3	17	4	2
	Bryozoa	10	4	6	3	2
Radiata.	Echinodermata	18	11	7	22	8
	Polyparia	26	8	18	10	5
	Foraminifera	0	0	0	0	0
	Amorphozoa	2	1	1	0	0
		156	75	81	59	32

created, being a large marine animal. Among the Annulata some genera of Tubicolous Annelidans appeared—so called from having lived in tubes. Among the crustacea as before, were some genera of Trilobites, but the period took its prominent character from the vast numbers of cephalopods, gastropods, lamellibranchia, brachiopods, crinoids, and polyparia, which swarmed in the seas.

277. The total number of species of mollusca and radiata alone, which existed in this period, as ascertained by the organic remains deposited in the stage, was 1198. These have been catalogued and described.*

The seas nourished marine plants, the discovery of many of which is due to Mr. Hall, of the United States. The continents were covered with a luxuriant vegetation, as appears from the rich deposits of coal found in the great basin of Sabero in Spain, which were long considered to have belonged to the succeeding period. The uniformity of temperature over the whole surface of

* Prodrome d'Orbigny, 52—109.

the globe, is proved by the existence of the same animal and vegetable remains in this stage, in all localities to which geological researches have been extended.

278. The configuration of land and water in this period has been determined on the principles already explained. The Hundsruck system of Elie de Beaumont, directed W. 31° S., having raised up the Silurian stage, increased the magnitude of the islands which existed in the previous period, created new ones, and gave to their coast its own prevailing direction. This will appear by reference to the map (fig. 144) sketched by M. Elie de Beaumont, showing the probable outlines of land and sea in Western Europe in the succeeding period. A tract of land arose above the waters on the west of Frankfort, and another on the S.W. of Strasbourg, which was united with the former continent. The central plateau of France was extended to the Pyrenees. The space included between the two islands of Brittany, which previously existed, was now filled up, and being united with the land round Cherbourg formed one continuous tract, which was connected on the one side with the southern part of England, and on the other with the Limousin by Poitiers. The land constituting the Scandinavian peninsula was also considerably increased. Upon several parts of this tract the Silurian deposits have never been since disturbed.

279. The seas of this period covered Asia Minor, Spain, Belgium, Germany, and Russia, as far as the Ural chain. The land which now forms the shores of the Frozen Ocean was also covered by these seas. In the east they extended from Asia Minor to China; in South America they covered all the tropical regions of Peru, Bolivia, and Brazil, and probably extended as far as the Falkland Islands, as is proved by the organic deposits found in all these regions. In North America they covered all the land which extends from Alabama to the state of New York. They also covered New Holland and Van Diemen's Land. Thus it appears that the Devonian sea extended in the Southern Hemisphere to 52° of latitude, and in the northern to the polar circle.

FOURTH PALÆOZOIC PERIOD.

280. The convulsion which terminated the previous period destroyed 59 generic animal forms, which never again reappeared upon the earth, as well as 1198 species of Mollusca and Radiata, besides all the species of the other classes. After an interval of tranquillity the earth was again repeopled, and once more clothed with rich vegetation. The new animal kingdom called into

existence is shown in the following table, exclusive as before of the Annulata.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Fourth Palæozoic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	1	1	0	1	1
	Fishes	46	33	13	37	27
Mollusca.	Cephalopods	11	3	8	6	2
	Gastropods	26	6	20	6	1
	Lamellibranchia	19	4	15	4	1
	Brachiopods	13	0	13	2	0
	Bryozoa	14	6	8	5	5
Radiata.	Echinodermata	18	11	7	17	10
	Polyparia	20	6	14	19	6
	Foraminifera	1	1	0	1	1
	Amorphozoa	1	0	1	0	0
		170	71	99	98	54

281. It appears that of former genera 99 were revived, while 71 new ones were created, making the total number of genera then existing on the earth 170. Besides these, however, there were at least 3 genera of Crustacea. This period was also signalised by the first unequivocal appearance of insects and Arachnida (scorpions) (fig. 143), the organic remains including besides Arachnida three orders of insects—the Coleoptera (beetles), the Orthoptera (crickets, locusts, grasshoppers), and the Neuroptera (dragon-flies).

282. Exclusive of the remains of animals of the other divisions, the number of species of Mollusca and Radiata alone ascertained to exist in this period, is 1047, which have been catalogued and described by M. D'Orbigny.*

* Prodrome, p. 110—162.

Fig. 142.—Configuration and relative extent of land and water in Western Europe during the Silurian period. *

THE PRE-ADAMITE EARTH.

CHAPTER IV.

283. Outlines of land and water.—284. The vegetable kingdom.—285. Coal deposits.—286. Convulsions which terminated the period.—FIFTH PALÆOZOIC PERIOD: 287. Composition of the strata—288. Destruction of the fauna and flora of preceding period.—289. The new animal kingdom.—290. Outlines of land and water.—291.

* The dark parts are supposed to represent land. This map is reproduced, with the permission of the author and publisher, from the Traité de Géologie of M. Beudant.

Changes of the continents.—292. Character of the fauna.—293. Absence of land animals—uniformity of climate.—294. Geological convulsions.—RETROSPECT AND RECAPITULATION OF THE PALÆOZOIC AGE : 295. Commencement of animalisation.—296. Prevailing forms. —297. Trilobites.—298. Characteristics of the carboniferous stage. —299. Carbonised vegetables.—300. Fossil vegetable species.—301. Their prevailing characters.—302. Contrasted with the present vegetable kingdom in the same localities.—303. Radiata of the carboniferous period.—304. Crustacea and insects.—305. Fossil scorpions. —306. Fishes of the carboniferous period.—307. Fossil fishes discovered by M. Agassiz. **Triassic Age.**—308. Triassic formation lies over the Palæozoic.—309. Geographical configuration—Map of France in Triassic age.—310. Vegetation. FIRST TRIASSIC PERIOD : 311. Outlines of land and water—character of animal kingdom.— 312. Chelonian reptiles (tortoises).—313. Foot-tracks of birds.— 314. Synopsis of animal kingdom. SECOND TRIASSIC PERIOD : 315. Mineral character of this stage—animal genera created and revived. —316. Outlines of land and water—animal kingdom.—317. Generic synopsis.

283. THE convulsions which produced M. Elie de Beaumont's system of the Ballons, pushed up certain parts of the Devonian stage, modifying the outlines of land and water, and augmenting the extent of the land. The map (fig. 144) represents approximatively the seas and lakes of this period as they existed in Western Europe.

284. Arborescent ferns, with their beautiful lace-like foliage; slender Lepidodendrons, fig. 145; Lycopodiaceæ (club-mosses), with leaves as varied and beautiful as the ferns; and gigantic Sigillaria, emulating the magnitude of the Conifers, abounded.

Assuredly no scenery upon the earth at present can convey an adequate idea of vegetation so luxuriant. Some of the mountainous regions of the torrid zone may convey a faint notion of it; but at the period to which we now refer, this magnificent flora covered the whole surface of the land from the tropics to Melville Island, now the regions of eternal frost.

285. By a dispensation of Providence, which cannot fail to excite sentiments of admiration and gratitude, this luxuriant vegetation of a remote epoch of the earth, flourishing countless ages before the creation of the human race, was destined to become for that race one of the most powerful agents of industry and civilisation. Buried in the earth by a long series of geological convulsions, it was submitted to the process of carbonisation, and converted into those vast beds of mineral combustible which now supply the materials out of which art and science have educed not only the means of artificial light and heat, but also a mechanical agent whose influence upon the condition of mankind is incalculable. To these precious deposits of the carboniferous

period are, in short, due the physical agencies by which the art of gas illumination, all the industries depending on the production

Fig. 144.—Map of Western Europe in the Carboniferous period, sketched by M. Elie de Beaumont.*

of artificial heat, and all the wonders effected by the steam-engine are due.

286. It is to the close of this fourth Palæozoic or Carboniferous period, and before the commencement of the Permian deposits,

* This map is reproduced from the Geology of M. Beudant, with the permission of the author and publisher.

that Sir R. Murchison assigns the date of the disruption of the earth's crust, which produced the Ural chain of mountains.

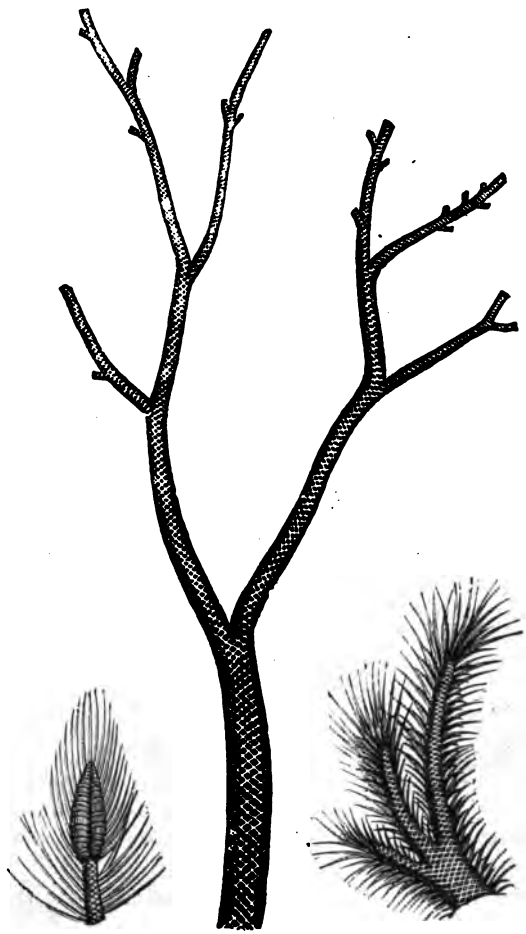


Fig. 145.—Lepidodendron Sternbergii.

M. Elie de Beaumont assigns to the same epoch the convulsions which produced the system which he has designated that of the North of England (211), the prevailing direction of which is

N. 5° W., and S. 5° E. M. d'Orbigny assigns to the same epoch the convulsion which produced the Chiquitean system of mountains in Bolivian Peru; and to the disturbance produced by one or all of these simultaneous convulsions, may be ascribed the destruction of the whole animal and vegetable kingdom which closed this fourth Palæozoic period.

FIFTH PALÆOZOIC PERIOD.

287. The strata which, in the regular series lie over the Carboniferous stage, have received the name of the Permian, from the Russian province of Perm, on the confines of Europe and Asia, which is traversed by the Ural mountains, this being the region in which the geological characteristics of this stage were first studied and determined by Sir R. Murchison. The component strata are commonly known to geologists as those of the magnesian limestone and new red sandstone, in contradistinction to the old red sandstone of the third Palæozoic or Devonian stage. That this stage has been separated from the carboniferous by a geological convulsion is rendered manifest by the discordance of the stratification in some places, and by the isolation of the stages in others, the Permian stage being found in some places without the Carboniferous under it, showing that it was there deposited in parts of the earth's surface which were dry land during the Carboniferous period.

288. The convulsion which terminated the Carboniferous period buried beneath its ruins nearly a hundred genera which never again appeared. Of the Mollusca and Radiata alone, exclusive of the other classes, 1047 species were destroyed by this catastrophe. All the vast forests which covered the extensive tracts of land were similarly buried, and form, as already explained, the coal-fields now found in the Carboniferous strata. This catastrophe was probably followed, as in the former case, by a period of tranquillity, during which a suspension of all animal and vegetable life took place. The seas, meanwhile, returning into their beds, the land was again divided from the waters, and the outlines of the new continents and islands became defined. The earth being thus gradually prepared, Omnipotence once more exerted its creative power, re-peopled the world, and clothed the land with vegetation.

289. The new animal kingdom, as far as its remains inform us, consisted of eleven new, and forty-five revived genera, making a total of fifty-six. Two of these belonged to the class of reptiles, twelve to that of fishes, and the remainder to the inferior divisions of the animal kingdom, as shown in the following

synoptical table—exclusive, however, of the Annulata, whose numbers cannot be so certainly ascertained.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Fifth Palæozoic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	2	1	1	1	1
	Fishes	12	5	7	6	3
Mollusca.	Cephalopods	2	0	2	0	0
	Gastropods	5	0	5	1	0
	Lamellibranchia	13	3	10	0	0
	Brachiopods	11	0	11	3	0
	Bryozoa	8	1	7	4	1
Radiata.	Echinodermata	1	0	1	0	0
	Polyparia	2	1	1	2	1
	Foraminifera	0	0	0	0	0
	Amorphozoa	0	0	0	0	0
		56	11	45	17	6

290. The seas during this period covered most probably the space occupied by the chain of the Vosges mountains in Europe, extending in a direction nearly N.N.E., through Rhenish Bavaria and the Grand Duchy of Baden, into Saxony and Silesia. The identity of the species of organic remains found in these deposits in Silesia, England, and Russia, proves that the seas of this period which covered the central part of England, from Glamorganshire to Durham, communicated with those of Russia, where they extended in the direction N.N.W. between the Ural chain and Novogorod, from the 48° of latitude to the Frozen Ocean.

They also covered Tasmania, in the Southern Ocean; and probably, therefore, extended over the entire surface of the earth from the 43° of south to the 80° of north latitude.

In the western part of continental Europe the outlines of land and water did not undergo any remarkable change. The great central plateau of France formed a large island, which extended to the south as far as the Pyrenees, as is indicated by the terrestrial plants now found in the deposits of Lodève, in the department of Herault, in France. The remainder of continental Europe consisted chiefly of a tract of land in Brittany. In England, besides parts of Devonshire and Wales, which were previously raised above the level of the ocean, a vast island was formed, extending N. 5° W. and S. 5° E., consisting of land forced

above the Carboniferous seas, and surrounded east and west by the waters of the Permian seas.

291. The Ural chain was also further heaved upwards, so as to form the series of mountains which now exist. In South America the continents were also considerably increased in extent in the west. The Chiquitean chain extended over some hundred leagues, from Brazil to the eastern extremity of the Andes. South America appears then to have had the form of a vast triangle, the length of which, from north to south, extended over 35° of latitude.

While the land underwent but little change in France, it was enlarged both in England and Russia, towards the east, by a considerable portion of the Carboniferous stage not covered by the waters of the Permian sea.

292. The fauna of this period were almost exclusively marine, a few, perhaps, being fluviatile. The two genera of reptiles were both fluviatile and marine. The fishes belonged to the Placoid and Ganoid families, of which the shark and sturgeon are living examples. Among the Mollusca, certain species of oysters first appeared in this period.

293. Although the organic remains present no traces of land animals, it is nevertheless probable that they prevailed upon the continents at least as extensively as in the previous period. M. Brongniart considers the vegetable fossils of this period to hold an intermediate place between those of the previous and succeeding periods. The marine fauna found in the Old and New World from the line to the 80° of latitude being identical in its character, demonstrates that central heat still neutralised the effects of solar radiation, so as to efface all isothermal lines, and that over the entire globe a tropical climate prevailed.

294. This period, like the others, was tormented by geological convulsions, of which the traces are found in the discordance of the stratification and the increased elevation of the immense surface constituting the Permian formation in Russia, in the dislocation which produced the Netherland range of mountains and those of South Wales. The effects of these geological perturbations are altogether in accordance with the superior limits of the fauna and flora of the Permian stage.

RETROSPECT AND RECAPITULATION OF THE PALÆOZOIC AGE.

295. With the Permian period was closed the Palæozoic age. The first assemblage of animated beings which peopled the earth included types of all the principal divisions of animal forms, but those of the lowest class most abounded. Thus, three animal and vege-

table kingdoms were called successively into existence, permitted successively to live, and were destroyed successively before any vertebrate animals superior to fishes existed; and even these were limited to the Placoid and Ganoid orders. No land animals had yet appeared. Reptiles made their first appearance in the fourth period, where they were represented, however, only by a single genus; and even in the fifth and last period, no more than two genera existed, one of which had been revived from the preceding period. During the entire age, not more than sixty-seven genera of fishes existed, and two of reptiles. Of the superior orders of birds and mammifers none were yet created.

296. The animal forms which most abounded were those of Tentaculiferous Cephalopods, Marine Gastropods, and Lamellibranchia, Brachiopods, Bryozoa, Echinodermata, and Polyparia, commonly known as zoophytes. Of the divisions of Annulata in this age but little is known, owing, no doubt, to the perishable nature of their structure. One family, however, of Crustacea, Trilobites, appeared during the first and succeeding periods in such numbers, as to confer upon the epochs a distinct organic character. These fossils have been long known in England under the local and erroneous name of *Dudley insects* or *locusts*, from their having been found in that district in such immense numbers. This remarkable family of Crustaceans did not survive the fourth Palæozoic or Carboniferous period, their principal development being in the Silurian and Devonian periods, which literally teemed with them. These crustaceans have no existing type, that which most resembles them being the Bopyrus, a small parasitical animal which attaches itself to the prawn, causing a large swelling in its body.

297. The fossil trilobites are generally from one to six inches in length, attaining, nevertheless, in exceptional cases to two feet. They were protected by a crustaceous shell or case, composed of annular segments, jointed one upon the other like those of the lobster's tail. This testaceous covering seems to have had a contractile power like that of the armadillo, since the animal is sometimes found more or less expanded, and sometimes coiled up. Owing to the absence of all traces of antennæ or feet, it is supposed that these animals adhered to rocks like fuci, or collected together in masses, forming conglomerations. Some naturalists, however, assume that they had locomotive power in water, either by soft paddles which have disappeared, or by skulling forward by means of the flexible extremity of their bodies. From the peculiar structure of the mouth it has been inferred that they were carnivorous, preying on naked mollusca or annulata, with which their remains are sometimes associated.

The curious and interesting structure of the eyes of the trilobite have been already noticed (62).

298. The most striking and imposing feature of the fourth or Carboniferous period of the Palæozoic age, consists in the numerous accumulations of vegetable remains which are presented in the coal deposits in all parts of the world. As the science of Comparative Anatomy has enabled the geologist to reproduce the forms and determine the habits and functions of the animal tribes which peopled the earth at these remote periods—in like manner the principles of Botanical Science have enabled him, basing his conclusion upon the visible structure of vegetable remains found in the coal beds, to reproduce, as it were, the vast forests of palms and arborescent ferns, the groves of conifers, and all the exuberant vegetation which flourished during the second, third, and fourth Palæozoic periods.

299. The layers of pure coal consist altogether of carbonised vegetables; and when it is considered that these strata are sometimes sixty feet in thickness, it seems difficult to explain how an accumulation of wood, plants, and foliage could ever be produced in such enormous quantity. Though the vegetable remains are always in a carbonised state, the leaves often possess such tenacity as to be separable from the stone. These and the seed-vessels which are found in iron-stone, have in many cases undergone metallic impregnation, which has in no degree impaired the delicacy of their structure. The coal plants have been determined to the number of nearly a thousand species, two-thirds of which are related to the ferns and the higher tribes of Cryptogamia, the remainder consisting of conifers and some flowering monocotyledonous (having only one seed lobe), and dicotyledonous (having two seed lobes) trees; numerous species, however, are still undescribed, and new forms are continually discovered.

300. More than two hundred species of plants have been discovered in the British coal-mines, but far greater numbers are found in the Carboniferous deposits of Europe, America, Australia, and even Greenland; and it is worthy of note, that in the coal-field on the shores of Lake Breton, fossil plants have been discovered identical with those found in the coal-mines of Northumberland, though these deposits have been made in opposite sides of the earth.

301. The prominent character of the vegetable kingdom during the Carboniferous period was the immense predominance of the vascular and higher tribes of Cryptogamic plants, with which were associated in a much less number, palms, conifers, cicadeæ, and other plants approaching to the character of Cacteæ and Euphorbiaceæ. Plants analogous to the tribes of Ductulosæ

abounded, differing, however, both in genera and species from those which at present exist. Thus fossil Calamites, related to the equisetum or mare's-tail, are found, which measure eighteen inches in circumference and thirty or forty feet in height, while the recent analogous species seldom exceed an inch in diameter and two feet in height. The fossil arborescent ferns called Sigillaria, measure sometimes fifty feet in height, having their summits covered with a splendid canopy of foliage. The foliage of the herbaceous species is extremely elegant, presenting endless varieties in their forms and in the skeletons of their leaves. The fossil arborescent club-mosses, called Lepidodendra (from a Greek compound signifying scaly tree), attain frequently an elevation of from sixty to seventy feet. Some of these trees have been found entire from their roots to their topmost branches. Their foliage consisted of simple linear leaves, spirally arranged round the stem. These leaves, in many cases, had been shed from the tree, the marks of their points of attachment never having been obliterated. In their external forms, the mode of ramification and the disposition of their foliage, they closely resemble the existing Lycopodiaceæ, or club-mosses. Notwithstanding the enormous disparity of magnitude between these latter and the fossil Lepidodendra, Brongniart has shown that both belong to the same family. The fossils were in fact nothing more than arborescent Lycopodiaceæ, analogous in magnitude to the largest existing pines, and forming extensive forests during the Carboniferous period, beneath whose shade flourished the lesser ferns and associated plants now found with them in the same coal strata.

302. The contrast which such a flora presents with that afforded by the woods and forests which now grow on the surface of the carboniferous districts of England is as striking as the discrepancy between the zoology of the Palæozoic formation and that of the present day.

303. Among the Radiata of the Carboniferous period are enormous quantities of corals denominated, according to their several forms, tubipora, syringopora, catanepora, &c. Of the Echinodermata, crinoids swarmed in such infinite numbers that entire strata are composed of their petrified remains. These species have also received names indicative of their forms, such as actinocrinus, cyathocrinus, and so on.

Among the shells of the Carboniferous period are found innumerable Foraminifera, which are detected in slices of Yorkshire limestone with the microscope. The upper strata of the mountain limestone of the lower Volga in Russia consist of masses of a minute species of fusulina, resembling grains of wheat. Entire

beds of mountain limestone or conglomerates are formed of shells of Brachiopods, such as spirifers, leptænæ, &c.

304. The Crustacea and Insects of the Carboniferous period have been less accurately ascertained than the other divisions of the animal kingdom. A few species of the fluviatile crustaceans, the Cyprides, are found in the coal deposits. Small crustaceans are also found in the iron-stone, which are referable to the limulus or king-crab, a genus which abounds in the seas of India and America. Dr. Mantell found in the iron-stone of Colebrook Dale several fossil beetles resembling the curculio or diamond beetle; he also discovered the wing of a large neuropterous insect closely resembling a species of the living Corydalis of Carolina.

305. With the insects imbedded in the coal strata are found the remains of those animals, to which they served as food. The fossil scorpion (fig. 143) already mentioned is an example of this. This fossil, which measures about two and a half inches in length, is embedded in coal-shale, with leaves and fruit; the legs, claws, jaws and teeth, skin, hair, and even a portion of the trachea, or breathing apparatus, are severally preserved. It had twelve eyes, the sockets of which remain. One of the small eyes and the left large eye retain their forms, and have the cornea or outer skin preserved in a corrugated or shrivelled state. The hairy covering of the animal is also preserved, being neither carbonised nor decomposed; the substance of which it consists, electrine, has resisted decomposition and mineralisation.

306. Among the fishes which lived during the Carboniferous period, and which, as already stated, are exclusively of the Placoid and Ganoid families, some genera are worthy of note.

Of the Sauroid fishes, two genera, one called the Megalichthys, is covered with enamelled smooth quadrangular scales, very thick, and nearly an inch wide. The head is protected by strong armour of enamelled plates. The teeth are large striated hollow cones. This fish was from three to four feet in length.

Another called the Holoptychius, attained in some instances the length of thirty feet. The scales were thin and circular, varying from one to five inches in diameter. The head is surrounded with a sort of shagreen helmet, having a surface irregularly ridged. It has large teeth of great density, some conical and others long and slender.

307. M. Agassiz has discovered about a hundred species of fossil fishes of the Devonian and third Palæozoic period, of which the most remarkable are the Cephalaspis, Pterichthys, and Coccosteus.

The Cephalaspis—a Greek compound, signifying buckler-head—received its name from the head being protected by a buckler or shield. The plates which cover it are united in a single osseous

case. The body is covered with scales, those of the head being highly ornamented.

The Pterichthys takes its name from two wings or lateral appendages, which, like the spines of the common bull-head, were weapons of defence. The head and fore part of the body are protected by large angular escutcheons—two eyes are placed in front of the lateral spines. The species of these which occur in the British strata are from eight to ten inches in length, but specimens of still greater length were found in Russia by Sir R. Murchison.

Triassic Age.

308. Above the Palæozoic formation a group of strata has been deposited, called the Triassic formation (47), consisting of the new red sandstone, muschelkalk, and variegated marls, or marnes irisées of the French. This formation has been generally considered as consisting of three stages. A scrupulous analysis of its composition, as well with relation to its fossils as to the conditions of its stratification, shows that, between the sandstone and the muschelkalk, there is no real distinction either geological or zoological. We shall, therefore, here, following D'Orbigny, consider the Triassic formation as consisting of two stages only; the first, or lower, called the Conchiferous; and the second, or upper, the Saliferous, from the prevalence of salt-mines in it; such, for example, as those of Salins, Lons-le-Saulnier, and Salzbourg.

309. The configuration of the land in this, as in the former age, is traced by observing the outlines of the strata, and the distinction of their organic remains. The convulsion which elevated the system of the Rhine (213) produced a general deluge, which devastated the earth, destroying altogether the vegetation which clothed it, and the races which peopled it in the last period of the preceding age. When the seas had retired to their new beds, and tranquillity was re-established, the outlines of land and water were defined. A great island seems then to have extended from the west of England across France to Austria, including Brittany, the Limousin, and Forez, throwing out two peninsulas, one towards the Pyrenees, and the other across the province of Burgundy (fig. 146).

Another island coincided in position with Belgium, throwing out a peninsula to the south, which extended over the Vosges and the Grand Duchy of Baden, its direction being parallel to the range of the Black Forest. The land previously uncovered in England, extending from Cornwall through Wales to Cumberland, was probably increased by a large surface, extending from Derbyshire to Durham. With these exceptions, the land seems to have remained generally as it was in the Carboniferous and Permian

periods. Since the Permian stage in Russia is not overlaid by the Triassic, it follows that the Swedo-Russian continent, at the commencement of the Triassic age, extended over all northern Russia, from the Baltic to the Ural Mountains, and from the shores of the Frozen Ocean to the government of Saratov.

Fig. 146.—Map of France in the Triassic age.

310. A great change was produced in the character of the vegetation compared with that of the former periods. The arborescent ferns and tall equisetacean trees which prevailed in such lavish profusion in the latter periods of the Palæozoic age, now existed in greatly diminished numbers, while the conifers and plants, analogous to the zamias and the cycadeæ, figs. 147, 148, formed an important feature of the flora, preluding the immense development which these classes underwent in the succeeding periods.

FIRST TRIASSIC PERIOD.

311. By the catastrophe which terminated the Palæozoic age, ninety-one species of Mollusca and Radiata, besides all the existing species of the superior classes, were destroyed, never to re-appear upon the earth. Seventeen generic forms also became extinct. When tranquillity was re-established, and land and water again became fitted for the maintenance of organised life, Almighty Power called into existence thirty-six new generic animal forms, and revived thirty-three, which formerly lived, making a total number of sixty-nine genera in the new animal kingdom. Independently of the species of the higher classes of animals, not so exactly ascertained, the genera of Mollusca and Radiata alone consisted of 107 species,* which have been catalogued and described.

The marine littoral and fluviatile deposits have supplied the means of tracing the shores of the seas of this period, and prove them to have been subject to the same atmospheric and tidal influences as those which affect the seas and oceans of the present

* "Prodrome d'Orbigny," vol. i. pp. 171—178.

epoch. Among the remains of this period are eleven genera of saurian reptiles, of most singular forms, among which are included the Labyrinthodon, the restoration of which by Professor Owen is given in fig. 109.

312. Chelonian reptiles (tortoises) now appeared for the first time, together with six new genera of Ganoid fishes. Crustaceous decapods, as well as acetabuliferous cephalopods (fig. 149), also

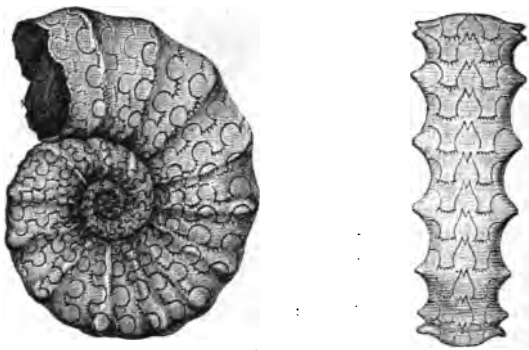


Fig. 149.—Ceratites nodosus (Fossil).

appeared for the first time, besides numerous lamellibranchia and echinoderms.

The Chelonians of this period are only known by the traces of their footsteps, which remain upon the rocks, figs. 108, 150.

Fig. 150.—Foot-print of the Chirotherium, a chelonian, or tortoise.

313. Numerous birds probably existed in this period; but, like

the chelonians, they have only left traces of their foot-prints (fig. 110). In fig. 151, are the imprints of the three fore phalanges of a

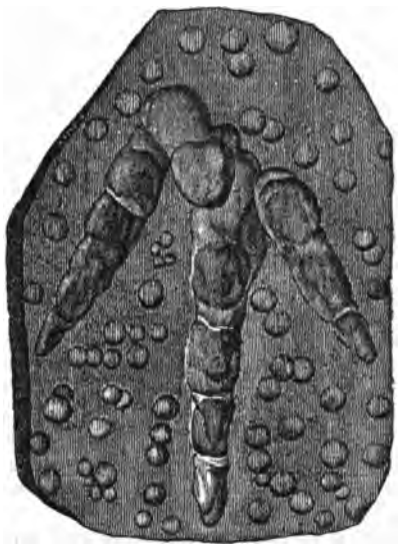


Fig. 151.—Foot-prints and marks of Rain-drops.

bird, accompanied by the curious incidental impressions of rain-drops which happened to fall at the moment the bird passed the spot.

314. *Synopsis of the Animal Kingdom (exclusive of the Annulata) during the First Triassic Period.*

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	?	?	?	?	?
	Reptiles	14	13	1	10	9
	Fishes	13	6	7	7	4
Mollusca.	Cephalopods	3	2	1	0	0
	Gastropods	9	2	7	0	0
	Lamellibranchia	17	5	12	0	0
	Brachiopods	3	0	3	0	0
	Bryozoa	2	1	1	1	0
Radiata.	Echinodermata	6	5	1	2	2
	Polyparia	1	1	0	0	0
	Foraminifera	0	0	0	0	0
	Amorphozoa	1	1	0	0	0
		69	36	33	20	15

SECOND TRIASSIC PERIOD.

315. The mineral character of this stage has been variously denominated, red marl, keuper sandstone, and variegated marls.

The effects of the perturbation which closed the Conchiferous period are visible in the discordances of stratification, as well as by the marked distinction between the fauna and flora.

The termination of the Conchiferous period was marked by the destruction of all the existing species, animal and vegetable, of which there were 107 species of Mollusca and Radiata alone. With that period twenty genera ceased to exist (314). The next act of creation was signalised by the appearance of thirty-five new generic forms, and the revival of fifty-nine, which previously existed.

316. The outlines of land and water continued to be nearly the same, but the seas were peopled with tribes different from those of the preceding period. Three new genera of reptiles, all of which were probably fluviatile, appeared. The seas possessed two new genera of fishes and ammonites, and various other Mollusca were now first called into existence, giving a special character to the new fauna, which, with that of the first Triassic period, seems to constitute a transition system from the Palæozoic to the Jurassic age.

No remains of the terrestrial animals of this period have been found; but the land was certainly clothed with a luxuriant vegetation, of which numerous species have been preserved, as already mentioned, figs. 146, 147.

317. *Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Second Triassic Period.*

		Genera.				
		Total.	Created.	Revived.	Extinct.	Charac-teristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	4	3	1	4	3
	Fishes	6	2	4	1	0
Mollusca.	Cephalopods	8	1	7	5	0
	Gastropods	20	4	16	2	0
	Lamellibranchia	22	5	17	1	0
	Brachiopods	7	0	7	4	0
	Bryozoa	1	0	1	0	0
Radiata.	Echinodermata	4	2	2	1	0
	Polyparia	12	11	1	2	2
	Foraminifera	0	0	0	0	0
	Amorphozoa	10	7	3	1	0
		94	35	59	21	5

Fig. 147.—Zamia pungens.

Fig. 148.—Cycas revoluta.

THE PRE-ADAMITE EARTH.

CHAPTER V.

318. Convulsion which closed the age. **Jurassic Age.**—319. Division of Jurassic formations into ten stages by M. D'Orbigny.—320. Nomenclature and thickness of the stages.—321. Section of the strata from the Vosges towards Paris.—322. State of the earth in the Jurassic age.—323. Jurassic age zoologically distingnished from the Triassic.—324. Distribution of the species into ten stages.—325. General inference respecting the distribution of specific forms.—326. Geography of Europe in Jurassic age—D'Orbigny's map.—327. The Anglo-Parisian basin.—328. The Pyrenean basin.—329. The Mediterranean basin.—330. Variation of the shores of these seas from period to period.—331. Discordances and isolation of the strata.—332. Corresponding observations on the organic deposits—333. Variations of the outlines of land during this age.—334. Change of condition of land between Toulon and Innspruck.—335. Accurate knowledge of the Jurassic geography.—336. Elie de Beaumont's Jurassic map.—337. Ichthyosaurus, Plesiosaurus, and Pterodactyle.—338. Other animals of the Jurassic age.—339. Coral reefs.—340. Insects.—341. The vegetable kingdom. First Jurassic Period. 342. Convulsion that closed the Triassic age.—343. First Jurassic stage determined by discordances and isolation of stratification.—344. Extent of the seas in Western Europe—remarkable discordances of stratification on the Alps.—345. Synopsis of the animal kingdom.—346. Reptiles, fishes and insects.—347. Convulsion which closed the period. Second Jurassic Period. 348. Mineral character of this stage.—349. Synopsis of animal kingdom.—350. Marine fauna.—351. No traces of terrestrial fauna.—352. Vegetation of the period.

318. The close of the Triassic age is identified with the convulsion to which M. Elie de Beaumont ascribes the elevation of the Thuringerwald system of mountains, including the Bœhmerwald-Gebirge, and the Morven ranges, the prevailing direction of which is W. 40° N. and E. 40° S. M. D'Orbigny assigns to the same date and cause the increased elevation of all the eastern part of the Andes, included between the 5° and 20° lat. S., and having the direction W. 50° N. and E. 50° S. By combining with these dislocations the numerous discordances of stratification which are observed, we shall find causes abundantly adequate to the explanation of the total and sudden disappearance of the flora and fauna of the Triassic age, to give place to the new creations of the succeeding one.

The Jurassic Age.

319. Upon the Triassic formation the Jurassic has been deposited, and is therefore the result of the next geological age. Many divisions of the strata composing this great formation have been proposed, some based upon the mineralogical characters of the strata, derived, however, in general, from observations more or less local, and others from an imperfect generalisation of prevailing fossils. We shall here adopt the analysis of this formation proposed by M. D'Orbigny. "After many years of laborious observation," says that eminent palæontologist, "during which we have only advanced from confirmation to confirmation, without encountering any inconsistent facts, we have arrived at the conclusion that the Jurassic formation consists of ten stages, or superposed zones, limited and defined by their several fauna as distinctly as by their stratigraphical characters. In tracing them one after the other around various geological basins, we have ascertained that they are nowhere confounded, and that they represent clearly ten distinct epochs, one succeeding another in a constant and regular order. We have ascertained that the same succession takes place in the same order at all parts of the earth which have been submitted to exact observation, and that they are therefore the indications of the series of great geological phenomena which have been manifested during the Jurassic age." *

320. M. D'Orbigny has given to these ten stages names taken chiefly from the places, where their mineralogical characters have been most developed and observed. To avoid encumbering the reader with a nomenclature so complex, we shall here designate the stages according to their order of superposition, or what is the same, their dates of deposition, beginning from the lowermost

* D'Orbigny, Paléontologie, vol. ii. p. 419.

or earliest, and proceeding upwards to the uppermost or latest. It may, nevertheless, be useful to indicate the names given to them in the works of M. D'Orbigny and other French geologists, annexing the estimated average thickness of the stages.

Stage.	Name.	Origin.	Thickness. Feet.
X.	Portlandian	Portland oolite and limestone	200
IX.	Kimmeridgian	Kimmeridge clay	500
VIII.	Coralline	Coral rag	1000
VII.	Oxfordian	Oxford clay	500
VI.	Callovian	Kelloway's rock	500
V.	Bathonian	Bath oolite	200
IV.	Bajocian	Bayeux	200
III.	Toarcian	Thouars	500
II.	Liasian	Lias	500
I.	Sinemurian	Semur	1000
		Total thickness	5100

These approximate estimates of mean thickness are much below the real measures on the slopes of the Alps, the western declivity of the Vosges, and through all the series from Avallon to Tonnerre.

321. In fig. 152 is presented a section of the Triassic and Jurassic formations extending from the Vosges to Sommevoire (Haute Marne), directed towards Paris,* where the series of strata is complete, the successive stages of each formation being marked with the Roman numerals.

322. From an elaborate examination of the strata composing these ten stages in various countries and in different parts of the globe, it appears, that during the Jurassic age, the earth was subject to all the physical vicissitudes which are at present incidental to it. During each of the ten periods there were continents and oceans. As at present, peculiar classes of marine animals inhabited the coasts, the deeper littoral parts, and the still greater depths of the ocean. Then, as now, there were submarine currents, waveworn shores, sheltered gulfs and tranquil bays. The condition of the strata proves that during this age slow undulations of the crust, such as those which are now manifested in the Scandinavian peninsula (118), were frequent. This is especially manifested by the state of the strata composing the 3rd, 4th, 5th, 6th, and 7th stages, at Chaudon, in the department of the Basses Alpes in France.

323. The Jurassic age is distinguished zoologically from the Triassic age by the absence of forty-two genera, which became

* For the continuation of this section to Paris, see § 396 and § 456.

extinct in the latter, and from the succeeding ages of the world

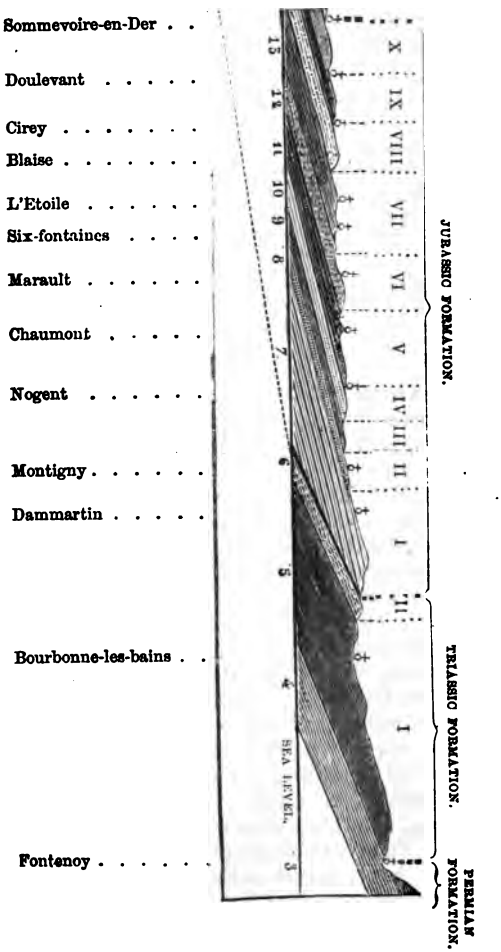


Fig. 152.—Section of the strata from the Vosges towards Paris.

by the absence of thirty-two orders of animals which had not yet appeared upon the earth, consisting of

	Orders.
Mammifers	11
Birds	6
Reptiles	2
Fishes	3
Crustacea	2
Insects	1
Mollusca and Radiata	7
	32

During this age nearly 300 new generic forms were called into existence, of which about 180 did not survive the age. This fauna consisted of about 4000 species, which were distributed among the ten periods, so that, save in very exceptional cases, no species are common to any two periods. Each period, therefore, had its own peculiar and characteristic animal kingdom.

324. To illustrate this remarkable principle, which seems to have been adhered to in all the operations of creative power from the first animalisation of the globe to the present period, we here subjoin a tabular synopsis, showing the number of species Mollusca and Radiata found in each of the ten stages, and also th number common to two or more stages.

Stages.	Species common to two or three stages.	Species limited to each stage.	Totals.
I.	1	173	174
II.	1	300	301
III.	0	288	288
IV.	7	596	603
V.	11	535	546
VI.	26	255	281
VII.	37	702	739
VIII.	27	628	655
IX.	16	183	199
X.	3	57	60
	129	3717	3846

But in the second column the same species is frequently repeated. Allowing for this, the total number of species which are found in more than one stage is only 56, or about $1\frac{1}{2}$ per cent. of the entire number, a proportion which is altogether insignificant, and which cannot be considered as impairing the general law that each period had its own specific fauna.

325. From a general analysis of the facts, the following conclusions may be deduced:—

1st. That during the Jurassic age of the world about 4000 specific animal forms lived, different from any which existed at any antecedent or posterior epoch.

2nd. That this total number consisted of ten distinct groups,

which existed severally during the ten periods of the Jurassic age, their remains being deposited in the ten superposed stages which compose the Jurassic formation.

3rd. That each period, therefore, had its own special fauna, having nothing in common with the preceding or succeeding period.

4th. That the species which, owing to accidental causes or erroneous designations, have been found in two or more stages, the number of which has been greatly overrated, do not in reality exceed 1½ per cent. of the total number of species discovered.*

326. The geography of Europe in the Jurassic age has been traced and mapped with considerable precision by Messrs. Elie de Beaumont and D'Orbigny. The Jurassic formation, which has been well observed, and its limits determined, shows the extent and configuration of the seas, and consequently the outlines of the land. The Jurassic seas in Western Europe formed three principal basins, extending over certain parts of France and the eastern and southern parts of England. The form and limits of these are shown on the map (fig. 153), drawn by M. D'Orbigny, here reproduced with the permission of the author and publisher, which does not differ in any essential points from that of M. Elie de Beaumont (fig. 154), as will presently appear.

327. The Anglo-Parisian basin covering the north-west of France and the eastern division of England, was limited in England by a line directed N.N.E. from Somersetshire to Durham, passing therefore through the counties of Gloucester, Worcester, Stafford, Derby, and York; all that part of England to the east of this line being then covered by the sea.

On the other side of the Channel, the western shores of this basin passed across Normandy from St. Lo southwards to Angers on the Loire. It skirted the northern limit of the central plateau from Angoulême to Autun. On the north its shores were directed from Calais by Arras to Metz and Verdun, where they turned southwards to Chaumont. This basin communicated with the other two by two straits, one of which extended from La Rochelle to the eastern part of Angoulême, marked in the map as the Breton Strait, and the other from Chaumont to Autun, marked as the Belgi-Vosgian Strait. All that part of the channel east of Devonshire constituted part of this Anglo-Parisian basin or sea. The entire province of Brittany in France was at this epoch dry land.

328. The Pyrenean basin was limited on the north by the Breton Strait, and on the north-east by the central plateau,

* D'Orbigny, Paleontologie, vol. ii. p. 426.

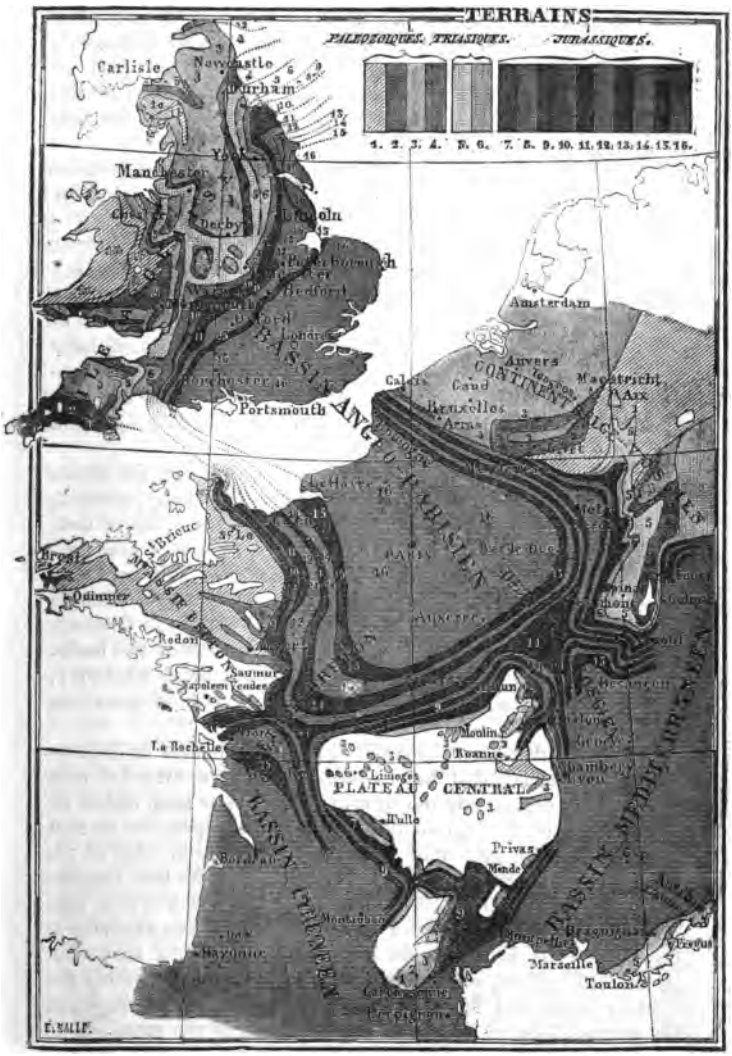


Fig. 153.*—Map showing the outlines of land and water in Western Europe in the Jurassic age. By M. D'Orbigny.

* In this map the dark shading, corresponding with the shades marked

which had been above the waters from the earliest geological dates. The southern limits of this basin are not so well ascertained, but it is certain that it covered all that part of southern Europe, from the surface of which the chain of the Pyrenees burst upwards at a later epoch, and extended far into the Spanish peninsula.

329. The third great European sea, called the Mediterranean basin, skirted the eastern side of the central plateau from the southern limit of the Vosgian Strait to Montpelier, where it was probably connected with the Pyrenean basin by another strait extending from Montpelier to Perpignan. This ancient sea extended in all probability to a considerable distance east and north-east, covering Provence and Dauphiné, all that part of Europe from which the chain of the Alps arose at a much later epoch, and all Piedmont, Switzerland, and Italy, with the exception of an island in the department of the Var in the south of France, which was already dry land in the preceding age, and continued so.

330. At each succeeding period of the Jurassic age, the shores of these seas retired from point to point within their preceding limits, so that their successive outlines formed a series of concentric lines, one included within the other, the seas retaining their form, but contracting their dimensions. This series of changes is especially remarkable in the case of the Anglo-Parisian basin, where it is indicated on the map (fig. 153) by the alternate shadings in two different tints around the borders of the basin. The limits during the first Jurassic period are those marked 7, the second 8, the third 9, and so on, the last or innermost being 16.

It appears, therefore, that each of the disturbances or dislocations, which terminated the successive periods, was attended with the effect of contracting the dimensions of these seas, either by the elevation of the surrounding land, or the depression of that which formed the bottom of the sea. The entire breadth of the zone of land, which being covered by the seas of the first Jurassic period was left uncovered by those of the last period of that age, is found to have been about a degree on the western declivity of the Vosges. It is a singular geological fact, that a succession of ten dislocations, each of which was sufficient to destroy the existing fauna and flora, should nevertheless leave unimpaired the general form of the seas, and that none of the more recent and more violent convulsions of the succeeding ages should have

7 to 14 inclusive, are to be understood as indicating water, and the other parts land.

effaced the traces, by which the outlines of the land and water during these successive periods have been determined.

331. It will be seen by reference to the section (fig. 152), that the series of stages from the Vosges towards Paris are still in concordant superposition, being very nearly parallel and horizontal, or if they dip it is always towards the middle of the basin, as strata do when deposited at present in tranquil waters. Except some occasional faults, there are no violently inclined or disrupted strata either in the Anglo-Parisian basin or north of the Pyrenean.

When, however, the state of the stratification of these stages on the slopes of the Alps are examined, a very different state of things is encountered. There we find them broken, and thrown into all inclinations, from the vertical to the horizontal; the obvious effects of the catastrophe, which in forcing up the great chain of the Alps burst through the Jurassic formation, disrupting its stages, and throwing them upon the declivities into all inclinations. On examining the sections of the strata as they are ranged upon the slopes of the Alps, we find, notwithstanding the violence to which they have been submitted, the same regular succession of ten stages occurring in the same order as around the Anglo-Parisian basin, where they were deposited successively, and in a state of comparative tranquillity. All this indicates that for long intervals of time previous to the elevation of the chains of the Alps and Pyrenees, the region on which they now stand was covered by the Jurassic seas, upon the bottom of which the strata of the Jurassic formation were deposited, and that it was long after the consolidation of these strata, that the violent action of the fluid matter of the internal parts of the earth, breaking the crust, forced the igneous rocks which now form the Alps and Pyrenees through the disrupted Jurassic stages.

332. Observations made upon the organic deposits of the Jurassic strata fully confirm these views. The shore lines of the Anglo-Parisian and other basins, those outlines marked on the map by the differently tinted shadings, are characterised by those shells which are deposited on the very borders of seas within the play of the tides. The deposits within these are those which take place in the deeper littoral regions, but those which are found upon the section of the strata disrupted upon the slopes of the Alps and Pyrenees, are the classes known to live only in the depths of the ocean. With the exception, therefore, of certain points giving coast indications, the Alps, or rather the space on which they stand, were in the midst of the Jurassic ocean.

333. During this age the island of the Var, already mentioned, was considerably increased. The land of the Vosges and the

Black Forest were also augmented, as well to the west in the direction of Lorraine, as to the east in the direction of Germany, where several islands, left separate in the Triassic age, became united so as to form a single island or continent of considerable magnitude. But while in some places the land was thus increased, in others it was submerged. Thus the continental tract, which in the Palæozoic age extended over France, between St. Malo and Lyons (see map of the Carboniferous period, fig. 148), was in this age submerged by the Breton Strait which connected the Anglo-Parisian and Pyrenean basins. Thus Poitiers and the surrounding region were alternately dry land and submerged by the sea, being submerged in the Silurian, dry in the Carboniferous period, again submerged during the Jurassic age, and finally raised to their present level.

334. It will be also apparent by inspecting the charts of M. Elie de Beaumont and D'Orbigny, that the tract between Toulon and Innspruck, which in the Palæozoic age was dry land, was completely submerged by the Mediterranean basin in the Jurassic age, being subsequently raised to its present elevation.

335. Owing to the extent of the Jurassic deposits in Europe, and the clearness with which they are distinguishable from those which lie below them, the outlines of land and water during that age can be traced with nearly as much precision as the geographical form of the existing continents.

336. The Jurassic geography of central Europe will be further elucidated by the map of M. Elie de Beaumont, fig. 154, here reproduced by permission from the work of M. Beudant.

The great Belgivosgian continent, a part of which only is included in the map of M. D'Orbigny, fig. 153, is here more fully represented. It appears that it extended on the north of the Mediterranean basin from Calais and Dunkirk to Cracow east and west, and from Wesel and Leipsic to Basle and Salzbourg north and south. By reference to fig. 142, 144, it will be seen that in the Silurian and Carboniferous periods Saxony and Bohemia formed a large island, and that another extended from Frankfort to Arras. In the Jurassic age these became united by the upheaving of the land, and formed the Belgivosgian continent shown in figs. 153 and 154. A well-defined coast then extended from Dunkirk to Metz, which, after passing round the two peninsulas, the Vosges and the Black Forest, reached Ratisbon, Vienna, and Cracow, where it was intersected by a strait directed N.W. and S.E.

An island existed between Toulon and Nice, and Corsica was raised above the waters.

Fig. 154.*—M. Elie de Beaumont's map of Western Europe in the Jurassic Age.

The Scandinavian peninsula remained unchanged since the Carboniferous period.

337. The marine animals of the Jurassic age presented characters strikingly different from those of the preceding epochs. The seas were now inhabited by monstrous animals endowed with vast powers of aquatic locomotion called Ichthyosauri, fig. 7, and

* The dark shading represents land.

Plesiosauri, fig. 155, whose oar-like feet resembled those of the

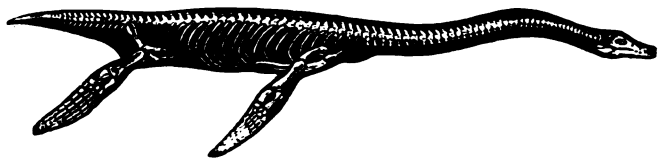


Fig. 155.—The Plesiosaurus.

present sea-tortoise. These animals replaced the sauroid fishes of the Devonian period which long before had disappeared. It was also this age which was signalised by those flying saurians to which palæontologists have given the name Pterodactyles (fig. 156), or wing-fingered. All these monstrous tribes became com-

Fig. 156.—The Pterodactyle

pletely extinct at the close of the Jurassic age. In fig. 161 (p. 1) we have reproduced, after Dr. Buckland, an illustration of the zoology and botany of this age.

338. The producti had altogether, and the spirifers nearly, disappeared, but numerous terebratulæ of other species took their places. The family of ammonites (fig. 8) which had commenced to appear sparingly in the Triassic age now abounded.

This age was also signalised by the appearance for the first

time of the family of *Calmars*, which include the Belemnites and various new bivalve Molluscs.

339. In the seas existed also madreporic reefs or islands similar to those which exist at present in intertropical regions (fig. 202). Lakes were numerous and were inhabited by tribes of fresh water Testacea, whose remains are now found in the Portland beds and elsewhere.

340. Insects of the orders Diptera (flies, gnats), Hymenoptera (bees, ants), and Hemiptera (bugs, water scorpions, plant lice), Crustaceous Isopods (sow bugs), Tectibranche-Molluscs, Cirride-Brachiopods, free Crinoids, severally appeared in this age for the first time upon the earth.

341. The vegetable kingdom presented none of the characteristics of the preceding. The colossal ferns and lycopodiaceæ had disappeared, and had been replaced by new species of the same families. Conifers were abundant in the Lias period, with new species of Cicadeæ. The fruit of a species of palm is found in the same deposit, as well as carbonaceous strata altogether different from those of the carboniferous period. The difference of the quantity as well as the quality of these vegetable deposits indicate in a striking manner the difference of the extent of the continents of the two periods.

This general account of the Jurassic age will render necessary only a very brief notice of its successive periods.

FIRST JURASSIC PERIOD.

342. The geological convulsion which closed the Triassic age having destroyed the animal and vegetable kingdoms, and the tumult having been followed by a period of tranquillity, the seas, subsiding within their limits, deposited the strata which form the first Jurassic stage. These deposits, called by D'Orbigny the Sinemurian stage, from the circumstance of their great development in the neighbourhood of the town of Semur (Sinemurium), correspond with the lower lias of British geologists, the gryphite limestone of Dufresnoy, Elie de Beaumont, and Roemer, and the quadersandstein of other German geologists.

The parts of Europe where this stage appears at the surface round the great Jurassic basins are shown upon the map (fig. 153), by the shading marked 7, being the external boundary of the series of concentric lines surrounding these basins. In England this stage is seen in a continuous zone, extending N.N.E. from Lyme Regis, through the counties of Dorset, Somerset, Gloucester, Worcester, Warwick, Leicester, Nottingham, and Lincoln. It

forms a semicircle in Yorkshire, directing its course to the Tees and Whitby. It will be apparent from the map that the course of this stage in England is only the continuation of its direction in Normandy.

343. This stage is distinguished from the succeeding one by many and evident discordances, and more especially by the isolation of strata, the superior stage being in many places present without the inferior. An example of this is presented at Fontaine-Étoupe-Four, in the department of Calvados in France, where the second, third, and fourth stages rest in concordant stratification on Silurian rocks, without the interposition of this first stage.

344. The seas of this period covered all the southern part of Western Europe from France to Sicily, and deposited their first stage upon the region on which the Alps and Pyrenees now stand. After the lapse of a long interval posterior to their consolidation, as well as that of many other stages subsequently deposited, the Alps and Pyrenees were forced by an internal pressure through the crust, which being broken, these with other strata were disrupted and thrown into various inclinations, some being rendered vertical, while others being compressed horizontally were bent into the form of undulations.

Examples of these effects are numerous. One showing the first Jurassic stage thrown into a vertical position occurs at Gevaudan in the department of the Basses Alpes (fig. 158), and one showing the undulating form produced by horizontal compression occurs at Chaudon à Digne in the same department (fig. 159).

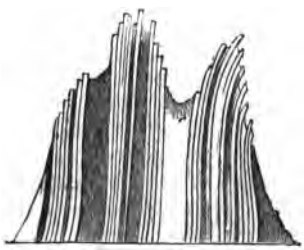


Fig. 158.—Section of first Jurassic stage at Gevaudan.

Fig. 159.—Section of first Jurassic stage at Chaudon.

345. After tranquillity was re-established, another fauna and flora was called into existence, a synopsis of which (excepting the annulata) is given in the following table :—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the First Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	1	0	1	0	0
	Fishes	1	1	0	0	0
Mollusca.	Cephalopods	4	3	1	0	0
	Gastropods	9	1	8	0	0
	Lamellibranchia	20	4	16	0	0
	Brachiopods	6	2	4	2	0
	Bryozoa	1	0	1	0	0
Radiata.	Echinodermata	3	1	2	0	0
	Polyparia	3	2	1	1	1
	Foraminifera	0	0	0	0	0
	Amorphozoa	0	0	0	0	0
		48	14	34	3	1

The 46 genera of Mollusca and Radiata composing this fauna, so far as they are known, consisted of 174 species.

346. Among the reptiles which lived in these seas were the Ichthyosauri or great fish-lizards, already mentioned (fig. 7), which rivalled in magnitude the largest whales of the present seas. Fishes of new species animated the coasts, and Ammonites (fig. 8), Belemnites and Turrillites abounded. So many new forms signalised the commencement of a new era in animalisation.

The order of Dipterous insects appeared for the first time. A new flora adorned the continents in which new species of Cicadeæ and ferns predominated.

347. The convulsion which terminated this period arose probably from a subsidence of the beds of the seas, which, after the re-establishment of equilibrium, caused them to recover their former outline, their shores being only contracted within their former limits.

SECOND JURASSIC PERIOD.

348. The deposits made by the seas of this period, called by D'Orbigny the Liasian stage, correspond with the middle lias or marlstone of British geologists, and the Belemniten-schichte of the Germans. The regions of its appearance are nearly the same as those of the preceding stage.

349. When tranquillity was re-established, a new creation was called into being, a synopsis of the chief part of which is presented in the following table:—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Second Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	3	1	2	0	0
	Fishes	29	22	7	10	9
Mollusca.	Cephalopods	3	0	3	0	1
	Gastropods	16	2	14	0	0
	Lamellibranchia	25	3	22	1	0
	Brachiopods	3	0	3	0	0
	Bryozoa	0	0	0	0	0
Radiata.	Echinodermata	6	4	2	0	0
	Polyparia	2	1	1	0	0
	Foraminifera	6	6	0	0	0
	Amorphozoa	0	0	0	0	0
		93	39	54	11	10

The genera of Mollusca and Radiata alone consisted of at least 300 species.

350. The seas swarmed with enormous Saurians in greater numbers than ever, including new varieties of the Ichthyosauri and Plesiosauri. The former had a fishlike form, and the latter a neck of enormous length, by means of which it could dart its mouth at a distant prey, its body still being immersed in the water (fig. 155). With these were associated the singular flying reptiles, called Pterodactyles (fig. 156). A vast variety of new species of fishes disputed the seas with swarms of Ammonites (fig. 8), Nautili, and Belemnites; while the coasts abounded in endless varieties of shells, such as Pterocera, Ditremaria, Inoceramus, with Asteria, Ophiuri, Echinodermata (fig. 160), and Foraminifera.

351. Although all traces of terrestrial fauna have disappeared, in the remains of this period there can be little doubt that insects and other Annulata existed. Of Crustacea only one genus, *Coleia*, has been found.

352. The land was richly clothed with vegetation, consisting chiefly of ferns, cicadeæ, and conifers of elegant foliage, of which 65 species are known.

Fig. 166.—Fossile Dragon-fly (Libellula).

THE PRE-ADAMITE EARTH.

CHAPTER VI.

Third Jurassic Period. 353. Mineral character of this stage.—354. Synopsis of the animal kingdom.—355. Outlines of land and water. —356. Land animals and vegetation. Fourth Jurassic Period. 357. Mineral character of the stage.—358. Synopsis of the animal kingdom.—359. Land fauna. Fifth Jurassic Period. 360. Mineral character of the stage.—361. Synopsis of the animal kingdom.— 362. Examples of the fauna.—363. Traces of land fauna—Phascolotherium and Thylacotherium.—364. Examples of the flora.—365. Convulsion which closed the period. Sixth Jurassic Period. 366. Mineral character of the stage.—367. Synopsis of the animal kingdom —disappearance of the Ichthyosauri.—368. Remarkable changes in the outlines of land and water.—369. Extent of the Mediterranean basin — submersion of the great Russian continent. Seventh Jurassic Period. 370. Mineral character of this stage.—371. Synopsis of the animal kingdom.—372. Creation of several orders of insects.—373. Specific forms of Mollusca and Annulata.—374. Outlines of land and water.—375. Marine flora.—376. Land animals.— 377. Surprising perfection of the fossil forms—observations of Buckland and Lyell.—378. Further proofs of the suddenness of the catastrophe which terminated this period.—379. Indication of the general prevalence of tropical climate. Eighth Jurassic Period. 380. Mineral character of the stage.—381. Synopsis of the animal kingdom.—382. Elevation of Russia above the waters.—383. Character of the fauna.

—384. Land flora and fauna.—385. Close of the period. NINTH JURASSIC PERIOD. 386. Mineral character of the stage.—387. Synopsis of the animal kingdom.—388. General character of the fauna.—389. Marine genera.—390. Land animals. TENTH JURASSIC PERIOD. 391. Mineral character of the stage.—392. Synopsis of the animal kingdom.—393. Outlines of land and water—marine fauna.—394. Close of the period. **The Cretaceous Age.** 395. Mineral character of the Cretaceous formation.—396. Section of the strata between the Vosges and Paris.—397. Resolution of the formation into seven stages.—398. Nomenclature and thickness of the stages.—399. Discordance and isolation of the stages.

THIRD JURASSIC PERIOD.

353. THE traces from which a convulsion closing the preceding period has been inferred, differ in nothing from those mentioned in the former period.

The strata deposited by the seas of this period, called by D'Orbigny the Toarcian stage, from the town of Thouars (Toarcium), in France, correspond with the upper Lias of British geologists, the Brauner Jura, and Opalinusthon of the Germans. Its extent can be traced on the map (fig. 153), by the shading marked 9.

354. The new creation, exclusive of the Annulata, is shown in the following table:—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Third Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	6	3	3	3	3
	Fishes	11	2	9	1	1
Mollusca.	Cephalopods	7	4	3	3	3
	Gastropods	17	0	17	1	0
	Lamellibranchia	29	2	27	0	0
	Brachiopods	4	0	4	1	0
	Bryozoa	0	0	0	0	0
Radiata.	Echinodermata	2	0	2	0	0
	Polyparia	3	2	1	2	2
	Foraminifera	3	2	1	0	0
	Amorphozoa	2	0	2	0	0
		84	15	69	10	9

The Mollusca and Radiata consisted of 288 species.

355. The outlines of land and water did not suffer any considerable change. Besides the genera of marine reptiles already mentioned, the strange forms of the Mistriosauri and Macrospondili

now roamed along the coasts, besides various new forms of Mollusca and Radiata.

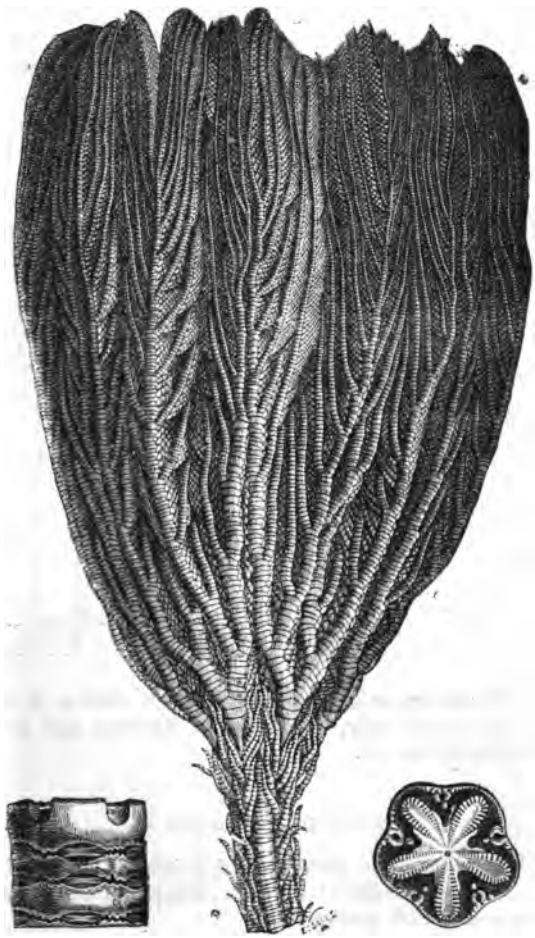


Fig. 160.—Pentacrinus fasciculosus (Echinoderm.)

356. Scarcely a trace of land animals remains, and those of plants but few and rare. Some conifers and cryptogamous plants however are found.

FOURTH JURASSIC PERIOD.

357. The strata deposited in this period, called by D'Orbigny the Bajocian stage, from the French town of Bayeux (Bajoce), correspond with the inferior Oolite of British geologists. Its course on the surface is indicated on the map (fig. 153) by the shading number 10.

358. The animal kingdom of this period is shown in the following table:—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Fourth Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	5	2	3	1	1
Mollusca.	Cephalopods	6	3	3	0	0
	Gastropods	21	4	17	1	0
	Lamellibranchia	40	6	34	1	0
	Brachiopods	5	1	4	0	0
	Bryozoa	8	8	0	1	1
Radiata.	Echinodermata	14	10	4	1	0
	Polyparia	18	7	11	1	1
	Foraminifera	2	1	1	0	0
	Amorphozoa	10	3	7	0	0
		129	45	84	6	3

359. Of the terrestrial fauna of this period nothing is known, and a few plants only, consisting of Cicadeæ and doubtful Monocotyledons remain.

FIFTH JURASSIC PERIOD.

360. This stage, the Bathonian of D'Orbigny and D'Halloy, corresponds with the great Bath oolite, Forest marble, and Stonesfield slate of British geologists.

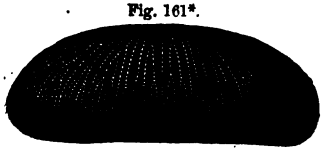
361. When tranquillity was re-established after the catastrophe which terminated the fourth period, a new creation appeared on the earth, of which the chief part is shown in the following table:—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Fifth Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	2	2	0	2	2
	Birds	0	0	0	0	0
	Reptiles	5	4	1	1	1
	Fishes	21	5	16	5	3
Mollusca.	Cephalopods	5	0	5	0	0
	Gastropods	25	6	19	0	0
	Lamellibranchia	38	4	34	0	0
	Brachiopods	6	0	6	0	0
	Bryozoa	19	9	10	2	1
Radiata.	Echinodermata	20	6	14	1	0
	Polyparia	19	8	11	4	3
	Foraminifera	5	0	5	1	0
	Amorphozoa	10	1	9	1	1
		175	45	130	17	11

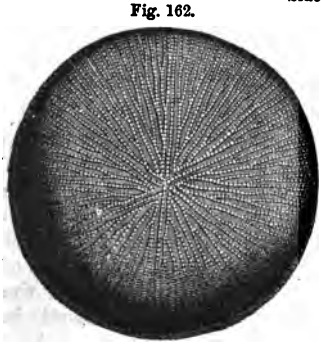
362. An example of the polyparia of this period is shown in figs. 160, 161*, 162.

Fig. 161*.



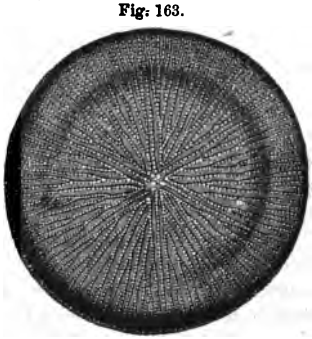
Side view.

Fig. 162.



Upper surface.

Fig. 163.



Lower surface.

Anabacia orbulites (Polyparia).

Together with new species of Pterodactyles, fig. 156, there lived in the seas of this period not less strange reptile forms, to which the names Pœcilopleuron, Teleosaurus, and Megalosaurus have been given.

363. A terrestrial fauna at length left traces of its existence. Mammifers now presented their first traces. Two land monsters, referred to this class, found in this stage, have been called Phascolotherium and Thylacotherium. Specimens of the lower jaw of the former were found in the oolitic limestone of Stonesfield. It is a small animal allied to the Marsupial family, and takes its name from the Phascolomys of New South Wales.

364. A great variety of species of ferns, Cicadeæ, and conifers have been found among the remains of this period, with a few Marsileaceæ, Lycopodiaceæ, and Equitaceæ.

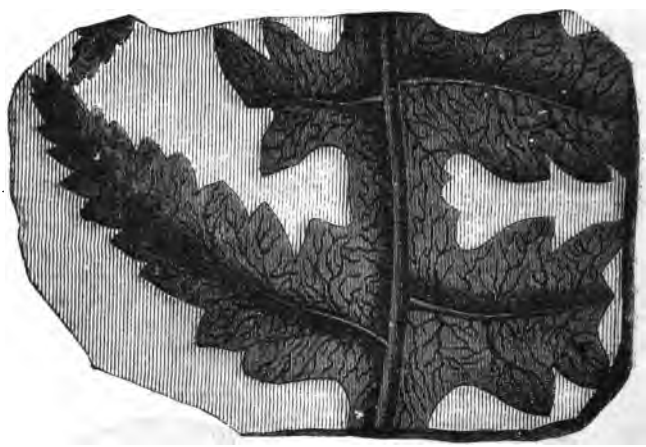


Fig. 164.—Phlebopteris Phillipsii.

365. One of the causes which are assigned to the catastrophe which closed this fifth Jurassic period, is the sudden sinking of the continent, which was elevated at the close of the palæozoic age, and which extended over Central and Northern Russia. This vast tract was submerged during the sixth Jurassic period, and the ocean at the same time flowed over the entire province of Cutch in India. The sea also covered the department of the Sarthe in France. Effects of this disturbance are traced in France, even where no disturbance of strata exists by the state of the superposed littoral deposits. Its effects are also seen in the polishing of the superior strata at Lyons, showing the result of a long-continued action of the waters. In fine, these indications are confirmed by the complete destruction of the fauna and flora of the period.

SIXTH JURASSIC PERIOD.

366. This stage, called the Callovian, corresponds to the Oxford clay and Kelloway Rocks of the British geologists, from the latter of which it takes its designation.

367. The animal generic forms which lived in this period, exclusive of the Annulata, are enumerated in the following table :—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Sixth Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	2	1	1	1	0
	Fishes	2	?	2	?	
Mollusca.	Cephalopods	6	2	4	1	1
	Gastropods	15	0	15	0	0
	Lamellibranchia	31	0	31	0	0
	Brachiopods	3	0	3	0	0
	Bryozoa	2	0	2	0	0
Radiata.	Echinodermata	11	0	11	0	0
	Polyparia	1	0	1	0	0
	Foraminifera	0	0	0	0	0
	Amorphozoa	0	0	0	0	0
		73	3	70	2	1

It appears, therefore, that of the 73 genera which existed, only three were new, two of which were generic forms of Cephalopods, called Rhychoteuthis and Palæoteuthis. This period was

Fig. 165.—Ammonite—Jason.

remarkable for the prevalence of Ammonites, denominated Limula, Athleta, Jason (fig. 165), as well as the Trigonia elongata, Plicatula peregrina, Astrea dilatata, and Terebratula Diphya.

The Ichthyosaurus appeared for the last time in this period.

368. The outlines of sea and land during this period underwent some remarkable changes. The convulsions which ter-

minated the fifth period raised the bottoms of the Breton and Vosgian Straits, so as to separate completely the Anglo-Parisian from the Pyrenean and Mediterranean basins, and thus to connect Brittany on the one side, and the Vosgian continent on the other, by two isthmuses.

369. The Mediterranean basin extended across the Tyrol, and into Switzerland, as far as Soleure, and probably even to the Crimea. But the greatest change produced by this convulsion was the subsidence of the great Russian continent, which had continued above the sea since the close of the palæozoic age, and the consequent extension of the seas of this sixth period over all Russia, from the 48th degree of latitude to the Frozen Ocean. It appears also from the organic remains of Mollusca and Radiata, that these seas extended on the south, without interruption, to the 9th degree of latitude, thus covering the entire extent of Asia, from the province of Cutch to the polar circle.

SEVENTH JURASSIC PERIOD.

370. The deposits of this period, called by D'Orbigny the Oxfordian stage, correspond with the upper strata of the Oxford clay, or the dark-blue clay of Oxfordshire and the Midland counties, the thickness of which in England, according to Lyell, is sometimes 500 feet. In the south-west of France, and in the Alps, it measures from 320 to 500 feet.

371. In the following table we give a synopsis of the generic forms of this period, excepting the Annulata:—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Seventh Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	11	10	1	9	9
	Fishes	28	14	14	18	13
Mollusca.	Cephalopods	9	5	4	2	2
	Gastropods	21	0	21	0	0
	Lamellibranchia	41	2	39	1	1
	Brachiopods	8	0	8	0	0
	Bryozoa	4	0	4	0	0
Radiata.	Echinodermata	22	9	13	8	7
	Polyparia	22	6	16	4	3
	Foraminifera	0	0	0	0	0
	Amorphozoa	16	5	11	8	2
		182	51	131	45	37

Of Crustacea 31 were created, all of which became extinct at the close of the period, so that the total number of generic forms ascertained to have lived is 213, of which 82 were created, and 131 revived, exclusive of other Annulata, the existence of which has been determined but their numbers unascertained.

372. This period is signalised by the first appearance of insects, of the orders Hemiptera (bugs, water-scorpions, plant-lice), Hymenoptera (bees, ants), and Lepidoptera (butterflies, moths), and of Isopodous Crustacea, and the prevalence of testaceous spongearia, pterodactyles, pycnodide fishes, and decapod crustacea.

373. Of Mollusca and Annulata of this period, 729 species have been catalogued, and the total number of species of all classes could not have amounted to less than 800.

In fig. 166 is shown a specimen of the insects of this period, and in fig. 167, one of the Annelids.

Fig. 167.—Serpula flagellum.

374. The seas retained their former limits; those of the Parisian and Pyrenean basins, however, retiring as before stated, so as to leave a new band of surrounding coast uncovered. They extended over the same parts of Europe, and were continuous on the one side to Asia Minor, and on the other into Russia, as is proved by the prevalence of the same marine species in the strata. The Breton and Vosgian Straits were still replaced by isthmuses.

375. Adolphe Brongniart has enumerated a considerable assemblage of marine plants of this period, consisting chiefly of Cryptogamous Algæ.

376. The continents were not less animated than the seas. Besides several orders of insects, and the generic reptile forms of the preceding periods, 10 new reptile genera were called into existence, including the Gnathosaurus, Pleurosaurus, Geosaurus, and Spondylosaurus, which, as well as new species of pterodactyles, abounded. M. Brongniart has also given a list of the

terrestrial flora of this period, which consisted in a great degree of doubtful monocotyledons.

377. The sudden character of the catastrophes, by which from period to period the successive faunas and floras were destroyed, is strikingly illustrated by the perfect state in which the remains of many of the saurians have been found. Of those which were deposited in these strata, many must, as Sir C. Lyell observes, have met with sudden death and immediate burial, and the same indications are observable in the case of all the other stages. "Sometimes," says Dr. Buckland, "scarcely a single bone has been removed from the place it occupied during life, which could not have happened had the uncovered bodies of these saurians been left, even for a few hours, exposed to putrefaction, and to the attacks of fishes and other small animals at the bottom of the sea." * Not only are the skeletons of the Ichthyosauri entire, but sometimes the contents of their stomachs still remain between their ribs, so that we can discover the species of fish on which they lived, and the form of their excrements. Not unfrequently there are layers of these coprolites (fossilised excrements) at different depths in the lias at a distance from any entire skeletons of those marine lizards, from which they were derived, as if the muddy bottom of the sea received small sudden accessions of matter from time to time, covering up the coprolites and other exuviæ, which had accumulated during the intervals. It is further stated, that at Lyme Regis, those surfaces only of the coprolites, which lay uppermost at the bottom of the sea, have suffered partial decay from the action of the water, before they were covered and protected by the muddy sediment that had afterwards permanently enveloped them.†

378. The remains of cephalopods give like indications of sudden death. Numerous specimens of the Calamary, or pen-and-ink fish (Geotenthis Bollensis), have also been met with in these strata at Lyme, with the ink-bags still distended, containing the ink in a dried state, chiefly composed of carbon and but slightly impregnated with carbonate of lime. These, like the Saurians, must therefore have been promptly buried, for if long exposed after death, the membrane containing the ink would have been decayed.‡

379. The identity of the specific forms of the fauna of this period, in all latitudes, from 40° to the Frozen Ocean, shows that

* Bridg. Treat. p. 125.

† Lyell's Manual, p. 327; De la Beche, Geol. Res., p. 334; Buckland, Bridg. Treat., p. 307.

‡ Buckland, Bridg. Treat., p. 307.

no difference of climates such as the present then existed. All had the intertropical character.

EIGHTH JURASSIC PERIOD.

380. The strata deposited during this period, called by D'Orbigny the Coralline stage, correspond to coral rag of British and German geologists.

381. Exclusive of annulata, the following table represents the fauna of this period.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Eighth Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	1	0	1	0	0
Mollusca.	Cephalopods	8	0	8	0	0
	Gastropods	28	2	26	2	0
	Lamellibranchia	41	2	39	2	1
	Brachiopods	4	0	4	0	0
	Bryozoa	3	0	3	0	0
Radiata.	Echinodermata	24	5	19	11	3
	Polyparia	48	26	22	25	19
	Foraminifera	3	1	2	1	1
	Amorphozoa	6	0	6	0	0
		161	36	125	36	24

382. In Russia, all that tract which extended to the Frozen Ocean, and which had been submerged during the seventh period, was now again raised above the waters, and became land. In England, France, and Germany the general forms of the land remained the same, but their extent was augmented by the general retirement of the shores of the seas.

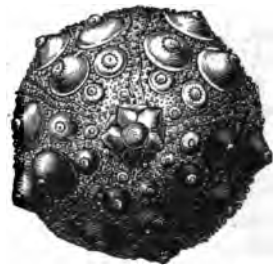
383. The fauna of this period was remarkable for numerous polyparia of the coral class, by which reefs were formed similar to those which exist in the present seas. It was at this epoch that the Diceras, Nerinea, Purpurina, Hemicidaris (figs. 168, 169), Acrocidaris, Millecrinus, and Apiocrinus attained their greatest specific development.

384. In the total absence of all organic remains of a terrestrial fauna, we must infer by analogy that the fauna of this must have been related to that of the antecedent periods. The flora, according to the observations of M. Brongniart, consisted of ferns, cicadeæ, and conifers of peculiar species.

385. Although it is probable that the close of this stage was the result of a convulsion which originated at some point distant

Fig. 168.

Fig. 169.



Hemicidaris crenularis.

from the range of geological observation, there are indications of some disturbance by the absence of the superior strata in the Alps, from Grasse to Gap, which may probably be connected with the catastrophe which closed this eighth period.

NINTH JURASSIC PERIOD.

386. The deposits of this period correspond with the Kimmeridge clay of the British geologists.

387. A general view of the fauna, with the usual exceptions, is presented in the following table.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Ninth Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	7	4	3	4	1
	Fishes	7	?	7 ?	3	?
Mollusca.	Cephalopods	3	0	3	0	0
	Gastropods	15	0	15	0	0
	Lamellibranchia	31	0	31	3	0
	Brachiopods	3	0	3	0	0
	Bryozoa	1	0	1	0	0
Radiata.	Echinodermata	10	0	10	1	0
	Polyparia	1	0	1	0	0
	Foraminifera	0	0	0	0	0
	Amorphozoa	1	0	1	0	0
		79	4	75	11	1

TENTH JURASSIC PERIOD.

388. The close of the last period was marked by the final extinction of at least 36 generic forms. The four generic forms of reptiles which appear for the first time in this ninth period are the Stenosaurus, Streptospondylus, Emys, and Platemys, of which the Stenosaurus is peculiar to the period and characteristic of it, not re-appearing in the next or any subsequent period. Of the reptile genera of former periods, those which re-appear in the present, and finally became extinct at its close, are the Plesiosaurus, Teleosaurus, and Pliosaurus.

Independently of the species of the other classes which lived in this period, 186 species of mollusca and radiata have been catalogued and described by M. D'Orbigny.

389. The seas were circumscribed by nearly the same limits, retiring nevertheless a little within their former shores. They were inhabited by nearly the same assemblage of genera, the species being, however, altogether different. The cephalopods were not numerous, the prevailing marine genera consisting of gastropods, and lamellibranchia.

390. The land, independently of some revived genera, was inhabited by the saurian reptiles Stenosaurus and Streptosaurus, and by the tortoise forms, denominated Emys and Platemys, all of which were probably amphibious.

No vegetable remains of this period have been found.

TENTH JURASSIC PERIOD.

391. The deposits of this period correspond with the Portland beds. They lie generally upon the Kimmeridge strata of the preceding period.

392. A general view of the fauna, with the previous exceptions, is given in the table on the next page.

Of the mollusca and radiata 63 species have been described.

393. The seas of this period, like those of the former, preserved the general configuration of their outlines, still retiring a little within their former shores. The marine fauna among fishes was increased by the Meristodon, and among mollusca by the Cyclas. The principal saurians of the last period disappeared from the coasts, and were replaced by the Cetiosaurus. This marine reptile must have rivalled the existing whale in magnitude, some specimens indicating a total length of 40 to 50 feet. The bones found in some strata in England, of somewhat more recent date, may have been carried up from the sea along the bed of a river by the tide, or the animal when living, as is often at present the case with existing cetaceans, may have wandered up the river, and dying, have been deposited in its bed.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Tenth Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	2	1	1	0	0
	Fishes	6	1	5	2	1
Mollusca.	Cephalopods	3	0	3	0	0
	Gastropods	6	0	6	1	0
	Lamellibranchia	16	1	15	0	0
	Brachiopods	0	0	0	0	0
	Bryozoa	0	0	0	0	0
Radiata.	Echinodermata	2	0	2	0	0
	Polyparia	1	0	1	0	0
	Foraminifera	0	0	0	0	0
	Amorphozoa	0	0	0	0	0
		36	3	33	3	1

394. The close of this period, which marks the termination of the Jurassic age, is distinctly indicated by numerous dislocations and isolations of the strata, denoting upheavings and depressions in many regions. These phenomena demonstrate the complete separation of the last stages of the Jurassic from the first of the succeeding age. M. Elie de Beaumont considers the catastrophe which raised the mountain systems of the Côte d'Or (215), of Monte Pila, and the Erzgebirge, the prevailing direction of which is W. 40° S. and E. 40° N., as that which terminated the Jurassic age.

The Cretaceous Age.

395. The group of strata to which geologists have given the name of the Cretaceous or chalk formation, being deposited upon the Jurassic group, must have been the result of the succeeding geological age. Its stratigraphical limits, as we shall here consider it, are the Purbeck beds below, and the Maestricht beds above. Some British geologists, including Sir C. Lyell, place the former as the uppermost strata of the Oolitic formation; while others, including Sir H. de la Beche, give it to the Cretaceous group. By reference to the tabular section (47), it will be seen that the title given to this Cretaceous group must not be understood as implying that chalk is the exclusive character of the strata.

The superior strata of this formation are not present in England, and hence they take their name from Maestricht, where they are most developed.

396. The complete series of strata of the Cretaceous formation, are found succeeding each other in their proper order in the continuation of the section given in fig. 152. This continuation, extending from Sommevoire and Vassy to Vertus, is given in fig. 170. The Cretaceous group terminates a little to the west of Vertus, and the Tertiary or succeeding formation appears from that point to Paris. We shall refer to this latter part of the section when we come to notice the Tertiary age.

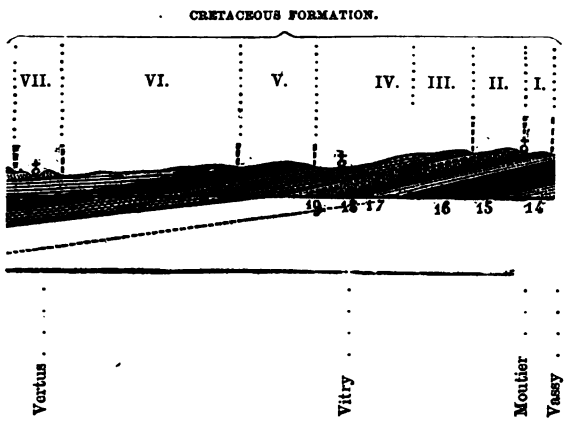


Fig. 170.—Section from Vassy to Vertus, being part of the great section from the Vosges to Paris.

397. Proceeding upon observations and reasoning similar to those explained in reference to the Jurassic formation (322), M. D'Orbigny resolves the Cretaceous formation into seven stages, to which names are given, derived from the localities severally where the strata are most exposed at the surface, and where therefore they have been most observed. To avoid encumbering the memory of the reader with a nomenclature so complex, we shall here, as in the former cases, designate the stages by their numerical order, proceeding from the lowest upwards, and the periods of their deposition into which the Cretaceous age is resolved, also by their numerical order, proceeding from the earliest to the latest.

398. It will be convenient, however, as in the former case, to indicate the names given to the stages and their approximate mean thickness severally.

No. of stage.	Name.	Origin.	Thickness. Feet.
VII.	Danian	Denmark	50
VI.	Senonian	Sen (Senones)	1000
V.	Turonian	Touraine	700
IV.	Cenomanian	Mans (Cenomanum)	1600
III.	Albian	Aube (Alba)	150
II.	Aptian	Apt (Apta Julia)	700
I.	Neocomian	Neufchatel (Neocomum)	8000
		Total	12200

So that the total thickness of the formation is above 12000 feet, or 2¼ miles, the chief part being occupied by the first or lowest stage. The mineral composition of these stages will be stated when we come to notice them separately.

399. While at some points these seven stages are found in regular superposition, in others particular stages are absent. Thus, while on the northern and eastern border of the Anglo-Parisian basin the series is complete, in other localities great discordances of stratification are observed, as well by the varying dips of the contiguous strata as by the absence of one or several stages of the series. These are the grounds upon which the entire Cretaceous formation is stratigraphically set apart from the Jurassic, and upon which the seven stages into which it is resolved are inferred to be independent, and those conclusions are confirmed by observations made upon the arrangement of the deposition of the organic remains, which appear to be distributed in seven distinct layers, corresponding with the stratigraphical limits of the stages.

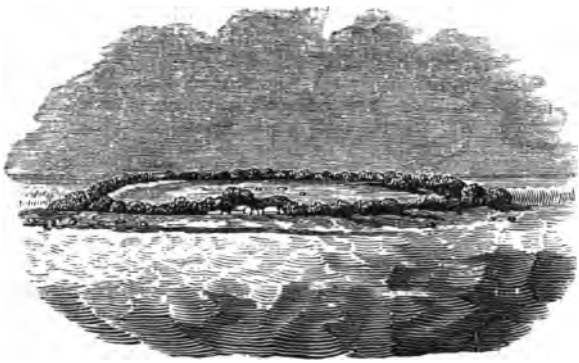


Fig. 202.—CORAL REEF.

THE PRE-ADAMITE EARTH.

CHAPTER VII.

400. Zoological character of the Cretaceous age.—401. Distribution of the species among the stages.—402. General conclusions.—403. Changes of the outlines of land and water.—404. Elie de Beaumont's map of Western and Central Europe—great geographical changes.—405. The Pyrenean basin.—406. Outlines of sea and land in Central Europe. —407. Site of the Alps.—408. Cretaceous geography of France and England—D'Orbigny's map.—409. Anglo-Parisian basin.— 410. The changes incidental to it from period to period.—411. Outlines of the basin in England.—412. Pyreneau basin—Mediterranean basin.—413. Animal kingdom—uniform tropical climate at all latitudes.—414. Prevalence of undulations of the surface—seven violent perturbations. FIRST CRETACEOUS PERIOD. 415. Dimensions and mineral composition of the stage—synopsis of animal kingdom. 416. Reptiles of this period—Iguanodon and Hylæosaurus.—417. Flora of this period. SECOND CRETACEOUS PERIOD. 418. Mineral character of the stage.—419. Synopsis of animal kingdom.—420. Outlines of land and water.—421. Marine fauna.—422. Vegetable kingdom.—423. Uniform tropical climate.—424. Close of the period. —THIRD CRETACEOUS PERIOD: 425. Mineral character of the stage. —426. Synopsis of the animal kingdom.—427. Outlines of land and water.—428. Marine and terrestrial fauna.—429. Close of the period.—FOURTH CRETACEOUS PERIOD. 430. Mineral character of the stage.—431. Synopsis of the animal kingdom.—432. Outlines of land and water.—433. Marine fauna.—434. Marine flora.—435. Undulations of the ground.—436. Close of the period. FIFTH CRETACEOUS PERIOD. 437. Mineral character of the stage.—438.

Synopsis of the animal kingdom.—439. Outlines of land and water. —440. Rich vegetation.—441. Great extent of land in Russia, South America, and India—termination of the period. SIXTH CRETACEOUS PERIOD. 442. Mineral character of the stage.—443. Synopsis of the animal kingdom.

400. THE Cretaceous age is zoologically distinguished from the Jurassic by the absence of upwards of 180 generic forms which existed in the previous age, and from the succeeding age by the absence of upwards of 500 genera not created until the succeeding one—these 500 genera consisting of 24 orders of animals, as follows:

	Orders.
Mammifers	11
Birds	5
Reptiles	2
Fishes	1
Crustacea	2
Insects	1
Mollusca and Radiata	2
Total	24

401. During this age about 270 genera were created, but it is by the specific forms that its fauna can be more distinctly characterised. These consisted of about 5000 species, of which about 700 belonged to the vertebrata and annulata. The manner in which the species of mollusca and radiata are distributed among the stages is as follows:—

Stages.	No. in two or more species.	No. limited to each stage.	Totals.
I.	7	844	851
II.	8	148	156
III.	8	402	410
IV.	8	841	849
V.	3	377	380
VI.	5	1574	1579
VII.	3	63	66
	42	4249	4291

The same species being repeated in the second column, a corresponding deduction from the total number of common species must be made, which will reduce the actual number of such common species to 21, being only a half per cent. of the total number.

402. From a general analysis of the facts, the following conclusions may be inferred:—

1° That there existed in the Cretaceous age above 5000 species of animals altogether distinct from those of the preceding and

following ages, and which therefore are characteristic of the Cretaceous age.

2° That this total number consisted of seven distinct groups, which existed successively during the seven periods of the Cretaceous age, their remains being deposited in the seven superposed stages which compose the Cretaceous formation.

3° That each period therefore had its own special fauna, having nothing in common with those of the preceding or succeeding periods.

4° That the species which, owing to accidental causes or erroneous designations, have been found in two or more stages, the number of which has been greatly overrated, do not in reality exceed a half per cent. of the total number of species discovered.

403. When tranquillity had been re-established after the catastrophe which closed the Jurassic age, the changes which had taken place in the levels of the solid surface of the earth caused the waters to settle into new beds, and gave a modified outline to land and sea. The contours of the seas of this period are now shown by the forms and limits of the Cretaceous strata, subsequently raised above the waters.

404. The outlines of land and water in Western and Central Europe, in the Cretaceous age, as sketched by M. Elie de Beaumont, are shown in the map (fig. 171).

The three great islands of the Jurassic age which appear in the map (fig. 154), were now connected, and their coast-lines completely changed. The northern part of Belgium was submerged, and Brussels, which in the former age was inland, was now on the coast. Arras, Calais, and Dunkirk, which were on or near the coast, were now at the bottom of a large gulf, in the midst of which was Paris, and at the southern part Tours. The town of Poitiers, which was situate in a strait, was now on the coast of the southern extremity of this gulf, which the reader will readily identify with the Anglo-Parisian basin so often referred to. London and Cambridge were at the bottom of this sea, the shores of which, bending westward, formed a bay, which might be called the gulf of Exeter, that city being at its westward limit. Oxford was on the coast of England, which, after jutting out eastward to a point near the site of Cambridge, turned northwards to Edinburgh. Holland and a large part of Prussia and Poland, including the cities of Amsterdam, Hamburg, Berlin, and Warsaw, were altogether submerged.

An isthmus connected the central tract of France with Brittany, at that time part of a continent, which, extending across the channel, was continued to the extreme north of Scotland, being there probably united with the Hebrides.

Fig. 171.*—Map of western and central Europe in the Cretaceous Age, sketched by M. Elie de Beaumont.

405. The Pyrenean basin, as will presently appear, did not exist at the commencement of the Cretaceous age, but subsequently to its third period reappeared, its waters covering the greater part of Spain, including Madrid, Burgos, and other towns, as shown on the map. Marseilles and Perpignan were at the bottom of a strait which bounded the southern part of the great central tract. A large

* The dark shading represents land.

island extended in the direction N.N.E. and S.S.W. from Briançon to Innspruck, separated from the main tract by a strait which covered that part of Europe now occupied by Switzerland and the chain of the Swiss Alps. A local sinking of the land between Dresden, Prague, and Brünn, in the middle of Germany, produced an extensive lake in that country, which in the Jurassic age was an uninterrupted tract of land. See map, fig. 154.

406. The Vosges Mountains, previously washed by the ocean, were now completely enclosed by the continental tract which connected Bohemia with the central plateau of France. The sea, which covered so large a part of these countries, now retired, leaving Langres, Nevers, Autun, and Lyons within the land. The south-eastern coast of the great central continent extended from Cracow a little to the north of Vienna and Munich, both of which were covered by the Mediterranean basin, following Strasburg, Bâle, and Lyons, to Carcassonne, where the Pyrenean and Mediterranean basins were connected by a strait between Perpignan and Bayonne. Bordeaux on the west and Avignon on the east were at the bottom of the sea.

407. The future base of the chain of the great Alps was then marked by the island already mentioned, which appears on the map between Salsburg and Briançon, on which Turin, Trente, and Innspruck are now placed. Toulon was on an island to the south of this, and Corsica already formed an island further south. The chief part of Italy was at the bottom of the Mediterranean basin. The Scandinavian peninsula had remained nearly as in the Jurassic age.

408. The geography of France and England during the Cretaceous age is shown upon a large scale and with more detail in the map (fig. 172), drawn by M. D'Orbigny and reproduced here by permission. In this map the seas are marked with the dark shading, and those parts which in previous ages were submerged are shown by three tints, indicated at the top of the map. The deposits of six of the successive periods of the Cretaceous age are marked as follows:—

I 17	III 19	V 21
II 18	IV 20	VI 22

409. It will be seen that the borders of the Anglo-Parisian basin on the south-east were, as in the former age, gradually contracted from period to period, that of the first period (17) being outermost, the next (18) within it, and so on, one being within the other until the last period. This regular succession of deposits is observable to a certain point of the border near Nevers, on the map, beyond which on south and west the exterior band of deposit is not, as

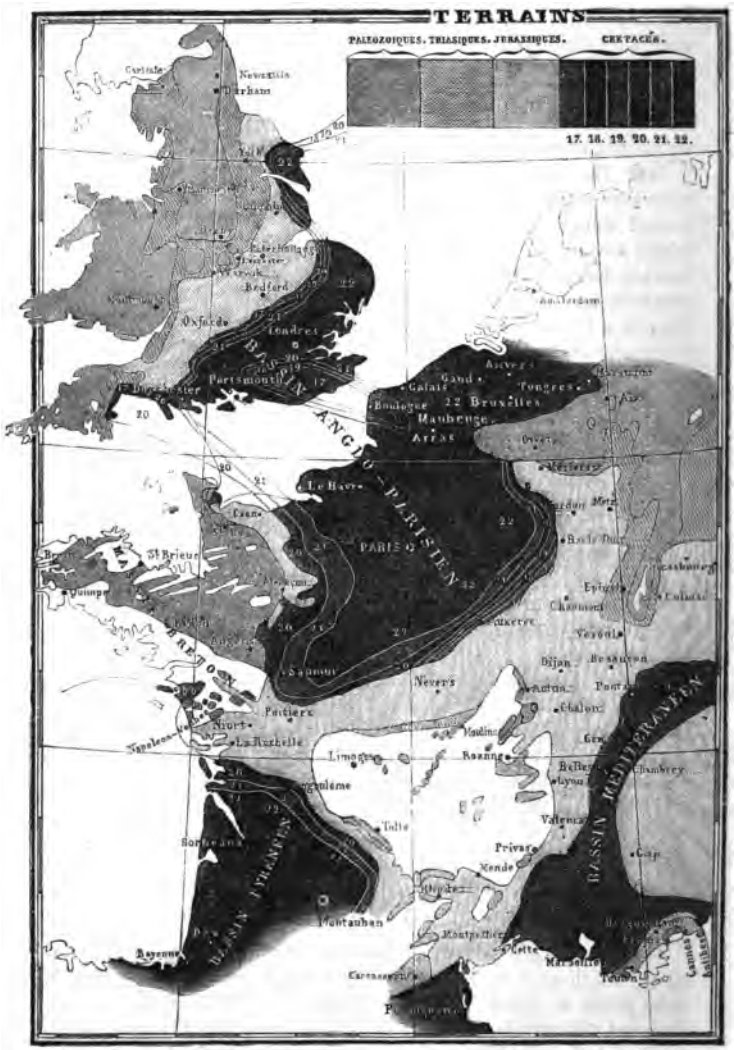


Fig. 172.—Map of France and England in the Cretaceous Age, drawn by M. D'Orbigny.

before, that of the first, but that of the fourth Cretaceous period (20).

410. The interpretation of this fact is evidently a change of relative level of the land along this border during the first four periods of the Cretaceous age. In the first, second, and third periods the border was subject to a gradually increasing depression, which after each period caused the shore of the sea to advance outwards, the shore of the second period (18) being outside that of the first (17), that of the third (19) outside that of the second (18), and in fine that of the fourth (20) being outside that of the third (19). The consequence of this is, that the fourth stage of the Cretaceous formation along this part of the coast lies over and conceals the previous deposits forming the first (17), second (18), and third (19) stages. But after the fourth period the relative levels must have undergone a contrary change, causing the borders of the sea to have retired inwards, or eastwards, from period to period, so that between the fourth and fifth period a band of deposit of the fourth stage (20) remained uncovered, and after the next period another (21), and so on to the end of the Cretaceous age.

411. The irregularity indicated above, as having taken place on the western side of the Paris basin, might have been expected to have continued across the channel, and to reappear along the English border of the same basin. Such, however, is not found to be the case; for, as indicated in the map, the successive stages of the Cretaceous period from the first (17) to the last appear along the northern border of the basin from Dorsetshire to Yorkshire, succeeding each other in the same regular order as in the southern border in France. It would, therefore, appear that the undulation which produced the irregularity observable along the western border adjoining Brittany must have been littoral; that is, in a direction at right angles to the N.W. and S.E. borders of the basin.

412. An examination of the Pyrenean basin discloses a singular state of things in accordance with that observed in the western border of the Parisian basin. The first three stages of the Cretaceous formation are altogether absent from the Pyrenean basin, which only received the deposits of the four last periods. M. D'Orbigny has inferred from this that during the first three periods of the Cretaceous age, the ground upon which the Pyrenean basin is placed was raised above the level of the sea, but that the convulsion which closed the third Cretaceous period caused it again to sink so as to be covered by the sea, and that it thus remained submerged during the last four Cretaceous periods. The border retiring from period to period is indicated on the map,

so as to leave band after band of the successive deposits each uncovered by the other along its NE. border.

In the Mediterranean basin all the stages are presented, though in an irregular and dislocated state.

413. The animal kingdom during the Cretaceous age was destroyed and reappeared in each of the seven periods. To the terrestrial animals, such as birds, reptiles, and insects, and the marine animals included in the class of fishes, mollusca, echinodermata, polyparia, foraminifera, and amorphozoa, which previously existed, must be joined for this age cycloid and ctenoid fishes (salmon and perch), and various forms of foraminifera hitherto unknown. This age was also signalised by the prevalence of cirridated brachiopods, bryozoa and testaceous spongiaria. Ammonite shells also, of the most elegant and various forms, abounded, which disappeared for ever after this epoch.

The presence during the entire Cretaceous age of the same genera and species of animals, from the line to the 56° of latitude on both sides of the world, prove that these regions, so entirely different in their climate at present, had a uniform temperature, proceeding evidently from the neutralising effect of the central heat of the earth, and which temperature was tropical.

414. Throughout the whole of this age, all that part of the earth to which geological research has been directed, was subject to the same slow and gradual undulations, as have been observed during the human period on the Scandinavian peninsula and elsewhere.

On seven different occasions, however, more violent geological perturbations took place, which swept from the earth and seas every living thing; and after these great catastrophes, when nature was tranquillised, Almighty power once more repeopled the land and the water, clothing the former with new vegetation.

FIRST CRETACEOUS PERIOD.

415. The great thickness of this stage, amounting at a mean estimate to 8000 feet, or above a mile and a half, shows that the duration of the period must have been considerable.

The composition of the stage includes the Purbeck beds, Hastings sand, Weald clay, and lower green sand of De la Beche, the Tilgate and Ashburnham beds of Mantell, and the Wealden or 15th group of Lyell.

The fauna, exclusive of Annulata, is presented in the following table:

FIRST CRETACEOUS PERIOD.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the First Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	2	2	0	2	2
	Reptiles	11	5	6	9	5
	Fishes	14	1	13	4	0
Mollusca.	Cephalopods	15	7	8	1	1
	Gastropods	30	9	21	0	0
	Lamellibranchia	50	9	41	0	0
	Brachiopods	11	5	6	0	0
	Bryozoa	13	3	10	1	0
Radiata.	Echinodermata	21	10	11	3	2
	Polyparia	27	12	15	7	6
	Foraminifera	11	4	7	0	0
	Amorphozoa	8	3	5	4	2
		213	70	143	31	18

One genus of crustacea (Archæoniscus) being added, gives the total number of genera known as composing the fauna 214, of which 70 had not existed in any previous period.

The two genera of birds called Palæornis and Cimoliornis were webfooted, and were the first of the order which had yet appeared. The Archæoniscus was of the order of isopodous crustacea.

Independently of the other classes, the number of species of mollusca and radiata alone catalogued and described is 851. An example of the mollusca is given in fig. 15.

416. Among the reptiles of this period were two of monstrous size, the Iguanodon and Hylæosaurus. The former, which has taken its name from some remote resemblance to the Iguana, a land-lizard of intertropical countries, had a body as massive as that of the elephant, measuring, when full grown, about 30 feet in length. It was herbivorous, feeding on the foliage of the ferns, cicadeæ, and conifers, which constituted the flora of the period.

The Hylæosaurus, scarcely less in magnitude, was also an herbivorous reptile.*

Besides these, the coasts abounded in tortoises; and reptiles of nine other generic forms, including the last of that strange class of flying reptiles, the Pterodactyle, which never reappeared on the earth after this period.

417. The land was richly clothed with vegetation. A catalogue of the plants has been published by M. Brongniart, who observes that the generic vegetable forms were nearly the same as in the

* Mantell—Wonders of Geology—p. 437.

Jurassic age, the cicadeæ, however, being less numerous in relation to the ferns. The flora consisted principally of cryptogamous acrogenous plants, such as the arborescent ferns, the marsileaceous, and equisetaceous classes; of dicotyledonous gymnosperms, such as cicadeæ and conifers, and of many of doubtful classes.

SECOND CRETACEOUS PERIOD.

418. The composition of the second stage of the Cretaceous formation corresponds nearly with the 14th group of Lyell, including the Speeton clay of Yorkshire.

419. A generic summary of the fauna (excepting the Annulata), is given in the following table:

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Second Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	3	1	2	0	0
Mollusca.	Cephalopods	10	1	9	2	1
	Gastropods	12	1	11	0	0
	Lamellibranchia	31	0	31	0	0
	Brachiopods	3	0	3	1	0
	Bryozoa	3	0	3	0	0
Radiata.	Echinodermata	2	1	1	0	0
	Polyparia	4	2	2	2	2
	Foraminifera	0	0	0	0	0
	Amorphozoa	1	0	1	0	0
		69	6	63	5	3

420. The outlines of sea and land in Europe did not differ much from their configuration in the preceding period. An island was formed on the present site of the Alps, extending from Castellane near Digue, in the department of the Basses-Alpes, to the department of the Hautes-Alpes. See map, fig. 172.

421. The marine fauna differed but little from that of the preceding period, consisting of numerous cephalopods of singular forms (fig. 173, 174).

422. That the land was clothed with vegetation is proved by the numerous remains of wood found in the strata. M. Brongniart has described a pine of this period, the cone of which measured ten inches in length, and an inch and three quarters in diameter, found in the bed of the Marne near St. Didier.

423. The identity of the tropical species found in extremely different latitudes, as, for example, in France and at Magellan's straits, lead to the same inference, as in former periods, of the general prevalence of an equatorial climate at all parts of the globe.

Fig. 173.—Ancyloceras Matheronianus.

Fig. 174.

424. The convulsion which closed this period was, according to M. D'Orbigny, that by which the Fuegian chain of mountains in South America, the direction of which was N. 30°. W. and S. 30° E., was raised.

THIRD CRETACEOUS PERIOD.

425. The deposit of this period corresponds with the 13th or gault group of Lyell, including the dark blue marl of Kent, the Folkestone marl or clay, and Blackdown beds and green sand and chert of Devon.

426. A view of the generic forms of the fauna is given in the following table:

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Third Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	1	1	0	0	0
Mollusca.	Cephalopods	11	0	11	1	0
	Gastropods	27	3	24	1	1
	Lamellibranchia	38	2	36	0	0
	Brachiopods	6	0	6	0	0
	Bryozoa	9	3	6	1	1
Radiata.	Echinodermata	16	6	10	2	1
	Polyparia	2	0	2	1	0
	Foraminifera	9	2	7	0	0
	Amorphozoa	4	1	3	0	0
		123	18	105	6	3

Adding two genera of Crustaceæ, the total number of generic forms in this period hitherto discovered amounts to 125, of which 20 were new, and 105 revived.

427. The outlines of land and sea were similar to those of the last period, except on the borders of the Anglo-Parisian basin between the departments of the Haute-Marne and Pas de Calais in France, which, hitherto uninvaded by the waters, were now submerged, which shows that the waters had advanced to the north in consequence of a subsidence of the ground in that quarter. The sea also extended to certain parts of the Eastern Pyrenees and the Var not previously submerged.

On the other hand, certain parts previously submerged were now dry land, as, for example, in the department of Vaucluse and along the line of the Alps from Escragnolles in the Var to Grenoble, all of which were covered by the sea of the previous period.

428. The seas were inhabited by fishes, Crustacea, and Mollusca,

Fig. 175.—Cyathina Bowerbankii.

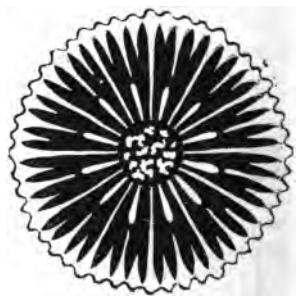


Fig. 176.

of numerous forms previously unknown. One of the Polyparia of this period is shown in figs. 175, 176.

FOURTH CRETACEOUS PERIOD.

No remains of terrestrial animals of this period have been found, and the only traces of vegetation are the remains of wood on the borders of the basins, with a few plants found at Lyme Regis and elsewhere.

429. Discordances in the strata indicate the convulsion which closed this period.

FOURTH CRETACEOUS PERIOD.

430. The fourth stage of the Cretaceous formation, called by M. D'Orbigny the Cenomanian, corresponds very nearly with the twelfth group, or upper green sand-stone of Lyell, including the Merstham fire-stone and the marly-stone, with chert of the Isle of Wight.

431. The generic forms of the fauna were as follow:—

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Fourth Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	2	1	1	1	1
	Fishes	3	1	2	0	0
Mollusca.	Cephalopods	10	1	9	1	0
	Gastropods	37	4	33	2	0
	Lamellibranchia	50	4	46	2	0
	Brachiopods	11	1	10	2	0
	Bryozoa	24	8	16	5	2
Radiata.	Echinodermata	25	5	20	5	3
	Polyparia	29	16	13	7	5
	Foraminifera	14	7	7	3	3
	Amorphozoa	18	6	12	2	1
		223	54	169	30	15

Among these a new genus of reptiles called the Raphiosaurus, and one of fishes called Otodus, were included.

432. The shores of the seas of this period underwent some changes, owing probably to a subsidence of the ground. They advanced in Belgium as far as Tournay. They covered also that extensive surface included between Fecamp and Tours, and between Tours and Bourges, submerging ground which had remained dry land since the close of the Jurassic age. They covered also the whole extent of the Pyrenean basin, from the department of the Loire Inférieure to that of the Lot, and from

thence to Spain and Portugal, which had hitherto remained dry land. In the Mediterranean basin the waters were limited to certain points, and from the prevalence of identical species of organic remains, it is probable that they extended in one direction without interruption to Mount Lebanon in Syria, and in the other into Germany, extending over Westphalia, Saxony, Silesia, and Bohemia.

The continents were somewhat extended on some of the borders of the basins, especially on the east of the Anglo-Paris basin in France, and upon its west in England; but they lost extent by the advancement of the sea, as already explained, in Belgium. The land was also diminished by the submersion of a large tract in the west of France, extending from the Loire to Havre.

433. The seas were animated by numerous fauna, consisting of fishes, new forms of Mollusca among the Gastropods and Lamellibranchia, and a great quantity of Brachiopods which formed extensive submarine banks. There were also innumerable varieties of Bryozoa, Echinodermata, and above all, of Polyparia. Of all the Cretaceous periods this was perhaps the most animated.

434. The shores of the seas were furnished with great varieties of marine plants—a catalogue of which with a description is due to M. Brongniart.

The terrestrial flora consisted principally of ferns, palms, cicadeæ, conifers, and dicotyledonous plants of uncertain families.

435. From what has been stated, it will be apparent that slow and local undulations of the ground, similar to what prevail at present in different parts of the earth, were common.

436. The convulsion which closed this period was that to which M. Elie de Beaumont ascribes the elevation of the system of Monte Viso (216), the direction of which is N.N.W. and S.S.E.

FIFTH CRETACEOUS PERIOD.

437. The fifth Cretaceous stage denominated Turonian by D'Orbigny, is identical with the eleventh or lower white chalk group of Lyell, including chalk without flints and chalk-marl. It is identical also with the upper plänerkalk of Saxony, and also with the chalk formation of Mantell.

438. The principal generic forms of the fauna of this period are shown in the following table:—

FIFTH CRETACEOUS PERIOD.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Fifth Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	0	0	0	0	0
Mollusca.	Cephalopods	5	0	5	1	0
	Gastropods	18	3	15	0	0
	Lamellibranchia	35	0	35	0	0
	Brachiopods	9	3	6	2	1
	Bryozoa	3	0	3	0	0
Radiata.	Echinodermata	11	1	10	4	0
	Polyparia	46	20	26	20	9
	Foraminifera	4	3	1	0	0
	Amorphozoa	4	1	3	1	1
		135	31	104	28	11

439. The outlines of the seas were nearly the same as in the former period; the shores, however, retired at several points, and especially in the Pyrenean basin, from the Loire Inférieure to La Vendée in the Mediterranean basin, upon all the known points, and in the chain of the Alps from La Malle in the department of the Var to Switzerland.

The continents underwent a corresponding change. The seas were very animated, as is evident from the vast number of Mollusca (fig. 14), and Echinodermata found upon the shores. They were also remarkable for numerous submarine reefs.

440. It would appear, from the fossil woods so frequently found, that the land was clothed with splendid vegetation, but owing to the destructive effects of the geological convulsion which followed, no complete remains either of plants or terrestrial animals have been found.

441. From the local absence of this fifth Cretaceous stage, it appears, that independently of several isolated points of land in France and Prussia during this period, a surface of dry land existed in Russia extending over 40° of longitude; another in North America measuring 30°; and others in South America and in India, which must have been above the surface of the waters, since no deposit corresponding with this stage appears there. Since all these regions were submerged in the succeeding period, it must be inferred that subsidence of the land over a great extent took place. This subsidence, according to M. D'Orbigny, extended from the torrid zone in the southern hemisphere to the 34° of latitude, and in the northern hemisphere to

the 56°, or over the immense extent of 90° of latitude, being a quarter of the terrestrial globe. In longitude this subsidence was not less extensive, and is assigned by M. D'Orbigny as the immediate cause which terminated the fifth Cretaceous period.

SIXTH CRETACEOUS PERIOD.

442. The sixth Cretaceous stage corresponds with the tenth or upper white-chalk group of Lyell, including the white chalk with flints of the north and south downs. It is identical with the strata called by the Italians la Scaglia.

443. A generic summary of the fauna is given in the following table:—

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Sixth Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	1	1	0	0	0
	Reptiles	5	3	2	1	1
	Fishes	41	24	17	22	15
Mollusca.	Cephalopods	12	0	12	10	0
	Gastropods	42	5	37	8	0
	Lamellibranchia	51	0	51	5	0
	Brachiopods	14	3	11	6	2
	Bryozoa	31	7	24	9	2
Radiata.	Echinodermata	34	11	23	19	6
	Polyparia	28	7	16	12	5
	Foraminifera	25	13	12	7	4
	Amorphozoa	24	7	17	21	6
		303	81	222	120	41

Adding two genera of Crustacea not included in this table, it appears that the fauna hitherto discovered consisted of 305 genera, of which 81 were new, and 224 revived from former periods.

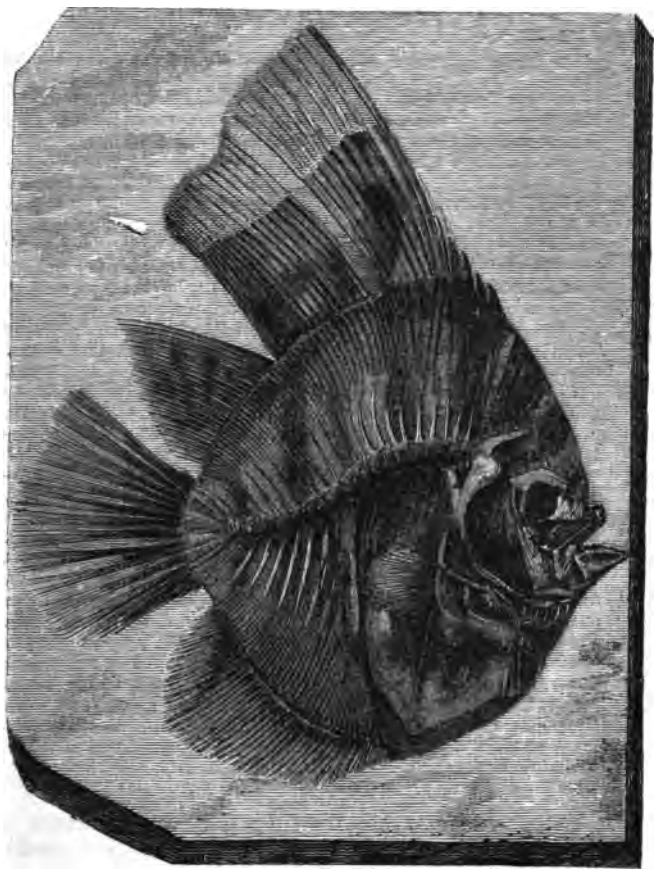


Fig. 184.—Platax altissimus.

THE PRE-ADAMITE EARTH.

CHAPTER VIII.

444. First appearance of fishes similar to the salmon and perch—specific forms of Mollusca and Radiata.—445. Great duration of the sixth Cretaceous period.—446. Great changes in the outlines of land and water.—447. Specimens of the fauna.—448. Flora and land animals

—the Mosasaurus.—449. Close of the period. SEVENTH CRETACEOUS PERIOD: 450. Mineral character of the stage.—451. Synopsis of the animal kingdom.—452. Examples of the fauna.—**Tertiary Age.** 453. Origin of the name.—454. Classification of the strata—five stages —their nomenclature and thickness.—455. Complete series not found. —456. Section of the formation between the Vosges and Paris—discordances and isolation.—457. Palæontological distinction between the Tertiary and inferior formations.—458. The number of species in the Tertiary age.—459.—Distribution of the species among the stages.—460. General conclusions.—461. Outlines of land and water —D'Orbigny's map of France and England.—462. Great geographical changes from period to period.—463. Character of the fauna—great development of Mammifers.—464. Uniform prevalence of tropical climate.—465. Gradual and violent undulations of the land. FIRST TERTIARY PERIOD. 466. Mineral character of the stage.—467. Synopsis of the animal kingdom.—468. Great development of fishes. —469. Vast increase of land animals, including those of which the rhinoceros, otter, dog, ferret, and squirrel are types.—470. Creation of flat-fish.—471. The Mollusca—nummulites.—472. Whole mountains formed of these animals.—473. Vast duration of the period.— 474. Terrestrial flora.—475. Outlines of land and water—Anglo-Parisian basin—form of its shores in France and England.—476. Pyrenean basin.—477. Mediterranean basin.—478. Its great extent towards the east.—479. Fresh-water lakes.—480. Close of the period. SECOND TERTIARY PERIOD. 481. Elevation of the Pyrenees—elevation of the tract of Bray in France, and of the Wealden in England.—482. Synopsis of the animal kingdom.—483. Specific forms of Mollusca and Radiata.—484. Creation of Cetacea, or whale forms.—485. Prodigious numbers of Miliolæ, of which the stone quarries of Paris are formed.—486. Marine flora—land animals, including the generic forms of which apes, bats, gallinaceous, predaceous, and climbing birds, serpents, rattle-snakes, baboons, and opossums are types.—487. Crocodiles and land tortoises—belemnites and nautili—terrestrial flora.—488. Outlines of land and water—division of Anglo-Parisian basin into two seas.

444. THIS period was signalised by the first appearance of fishes of the Cycloid and Ctenoid orders (salmon and perch), and also by numerous genera of Foraminifera. The number of species of Mollusca and Radiata alone which entered into the composition of this fauna was 1577, all of which were new to animated nature, and all of which disappeared at the close of this period.

445. The great thickness of the stage, measuring, as we have seen, 1000 feet, and the great number of species found in it, lead to the conclusion that this sixth period was one of the longest of the Cretaceous age.

446. The seas of this period underwent considerable changes both in France and England. In some parts their shores retired, leaving increased tracts of dry land, while in others, as in the department of La Manche in France, tracts hitherto dry were

submerged. Great changes were also produced at other points. Thus it was at the commencement of this period, that in consequence of a considerable subsidence of the land, the sea flowed over all Belgium as far as Maestricht, covering land which had remained dry since the close of the Palæozoic age. It was also during this period that the sea extended its limits from Snowdon to the Ural Mountains, over an extent of 40° of longitude. It also covered a surface of 30° upon the southern coast of South America. It covered also Chili in the western continent, and Pondicherry in the eastern. From the identity of the marine deposits, it may be inferred that the sea of this period extended without interruption from France to all those distant points and from the tropics to the 56° north, and the 34° of south latitude.

Fig. 177.—Spondylus spinosus.

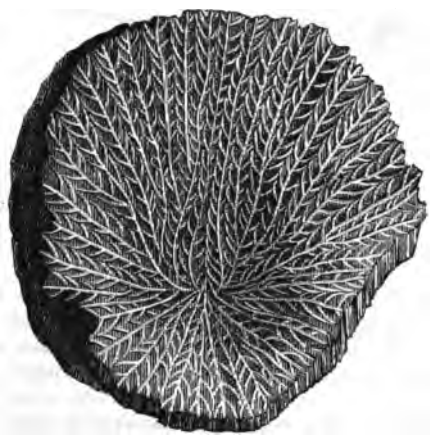


Fig. 178.—Reticulopora obliqua.

The land underwent changes corresponding with those of the seas, being everywhere augmented where the seas retired, and diminished where they advanced.

447. The Cycloid and Ganoid fishes prevailed in great numbers.

in the seas, which were also animated by an infinite variety of Mollusca—Gastropods, Brachiopods, Lamellibranchia (fig. 177), and Bryozoa (fig. 178).

448. The shores of the seas were abundantly furnished with marine vegetables. Of terrestrial animals, one genus of birds, called Scolopax, has been found: and of land reptiles, two genera, Leidon and Mosasaurus. The jaws of the latter are shown in fig. 179.

449. The geological convulsion which terminated this period,

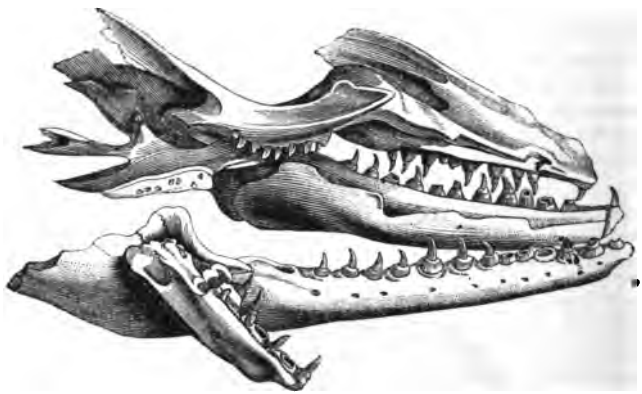


Fig. 179.—Mosasaurus Camperi.

according to M. D'Orbigny, was that which raised the chain of the Cordilleras of Chili, the direction of which is N. 5°. E. and S. 5°. W.

SEVENTH CRETACEOUS PERIOD.

450. In every point of view, this is the least important of the periods, being the last stage of the decadence of the Cretaceous age. This stage has no representative in the British strata. It is identified by Sir C. Lyell with the Maestricht beds, a group of strata observed near that city, on the banks of the Meuse, having the thickness of about 100 feet. It rests upon the ordinary white chalk and flints, which form the sixth Cretaceous stage, and contains fossils, which, according to Sir C. Lyell, are, on the whole, very peculiar, and all distinct from those of the Tertiary age, which immediately succeeded it.

451. The following is a general view of the fauna of this period, so far as the fossil remains show it.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Seventh Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	1	0	1	1	0
	Fishes	?	?	?	?	?
Mollusca.	Cephalopods	2	0	2	1	0
	Gastropods	17	1	16	0	0
	Lamellibranchia	11	0	11	0	0
	Brachiopods	2	0	2	1	0
	Bryozoa	0	0	0	0	0
Radiata.	Echinodermata	4	1	3	1	0
	Polyparia	8	0	8	5	0
	Foraminifera	0	0	0	0	0
	Amorphozoa	1	0	1	0	0
		46	2	44	9	0

452. Independently of some Saurians, fishes, Crustacea and Annelides, found among the fossils, sixty-six species of Mollusca and Radiata have been catalogued by M. D'Orbigny, of which only two are common to this and the preceding period. Of these, a considerable number, including the Nautilus Danicus (figs. 9, 10, 11), are found in this stage in Sweden as well as in France, and may be regarded as more especially characteristic of the closing period of the Cretaceous age.

The Tertiary Age.

453. At an early date in the progress of the science, the strata below the Jurassic formation were called primary, and the Jurassic and Cretaceous formations, taken together, were denominated secondary, having been obviously deposited from the seas of that era upon the former. Hence the most recently deposited group of strata resting upon the Cretaceous formation, and immediately subjacent to the diluvial and alluvial deposits of the human period, received the name of Tertiary, which, by general consent, they have retained, although subsequent discoveries have shown that the preceding deposits, instead of being resolved into two, are much more properly regarded as consisting of a greater number of distinct groups.

454. The strata composing the Tertiary formation have been very variously classed, and grouped in geological works. Sir Charles Lyell has divided them into three principal groups, which

he calls Eocene, Miocene, and Pliocene. He divides the first into three, and the last into two subordinate groups, thus making the whole formation consist of six stages. M. D'Orbigny finds that a division into five stages is more in accordance with the distribution of the organic remains. The following are the names which he has given to the five strata, with their origin, and their estimated average thickness:—

No. of stage.	Name.	Origin.	Thickness.
V.	Sub-Apennine	Apennines	Feet 2000
IV.	Falunian	Falun (conchiferous crag)	1000
III.	Tongrian	Tongres	330
II.	Parisian	Paris	3300
I.	Suessonian or Nummulitic	Soissons	3300
		Total	9930

Although these estimates of thickness must be regarded as mere approximations, they will, nevertheless, be useful as exponents of the relative duration of the five periods into which the Tertiary age is divided. The total average thickness of this Tertiary formation would appear to be about 10000 feet, or two miles, the chief parts being occupied by the two lowest stages.

455. The complete series of stages can scarcely be found in any single locality, but, partially united, their order can be easily determined by comparing sections made in different places.

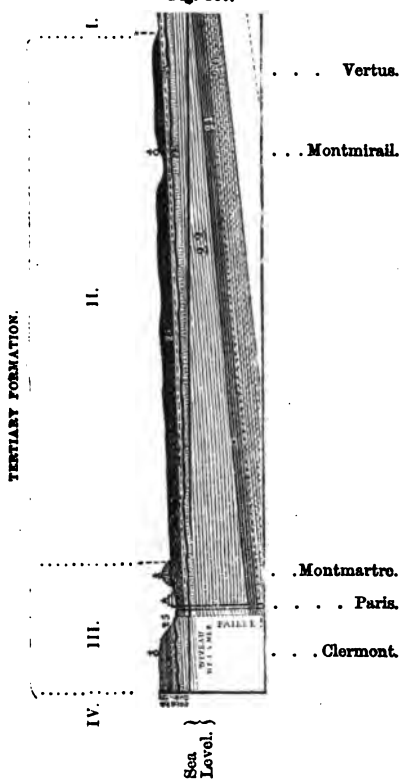
456. Fig. 180 represents a section from Vertus to Paris, being the continuation of the general section of the country from the Vosges to Paris, the first three divisions of which, commencing from the Vosges, have been already given in figs. 141, 152, and 170. In this section, the first three only of the stages, proceeding upwards, are included, being numbered 24, 25, and 26.

As in the preceding formations, the single stages are distinguished one from another, partly by discordance of stratification, but much more by what geologists call discordances of isolation; that is, by the appearance of certain stages, and the absence of others. For example, while round the Anglo-Parisian basin the first of the Tertiary stages is deposited immediately upon the last of the Cretaceous; in other places many intermediate stages are wanting. Thus, near Orgon, in France, the first Tertiary stage is deposited upon the first Cretaceous, all the other six stages of the Cretaceous formation being absent. In like manner, in the department of the Aude, the first Tertiary stage is deposited upon the Palæozoic formation; and in the department of the Var and the Lower Alps upon the Jurassic formation. In

like manner, throughout the province of Touraine, the first and second Tertiary stages are absent, the third being deposited in different localities upon the Azoic, Palæozoic, the Juraàsic, or the Cretaceous formations.

457. Palæontological considerations supply other distinctions between the Tertiary and inferior formations. Nearly 230

Fig. 180.



generic forms extinct at the close of the Cretaceous age, and not appearing in the Tertiary age, constitute a distinguishing characteristic between the two epochs. In like manner, at the commencement of the human period, 1324 new generic forms were created which had no previous existence, and which, not being present in the Tertiary age, supply a distinction between it and the human epoch.

458. The number of species of plants and animals of every order which lived in the Tertiary age, greatly exceeds that of any former period. The number of vegetable species found in the Tertiary strata exceeds 600, and that of Vertebrata and Annulata amounts to nearly 1500, while the number of Mollusca and Radiata, catalogued and described as belonging to this age, amounts to 6042.*

459. The proportion in which this vast number of specific forms of Mollusca and Radiata are distributed through the five Tertiary stages is as follows:—

Stages.	No. in two or more stages.	No. limited to each stage.	Totals.
I.	8	670	678
II.	8	1568	1576
III.	0	428	428
IV.	28	2726	2754
V.	83	523	606
	127	5915	6042

The same species being repeated in the second column, a corresponding deduction of the total number from the common species must be made, which will reduce the actual number of the common species to ninety-one, which is equivalent to 1½ per cent. of the total number.

460. From this and other observations made upon the strata composing the Tertiary formation, the following conclusions have been adduced:—

1°. That there existed in the Tertiary age above 8000 species of animals, altogether distinct from those of the preceding and following ages, and which, therefore, are characteristic of the Tertiary age.

2°. That this total number consisted of five distinct groups, which existed severally during the five periods of the Tertiary age, their remains being deposited in the five superposed stages composing the Tertiary formation.

3°. That each period therefore had its own special fauna, having nothing in common with those of the preceding or succeeding periods.

4°. That the species which, owing to accidental causes or erroneous designations, have been found in two or more stages, the number of which has been greatly overrated, do not in reality exceed 1½ per cent. of the total number of species discovered.

461. The seas of this age in Western Europe consisted of four,

* Prodrome D'Orbigny, vols. ii. and iii.

three of which, the Anglo-Parisian, the Pyrenean, and the Mediterranean basins correspond with those of former epochs.

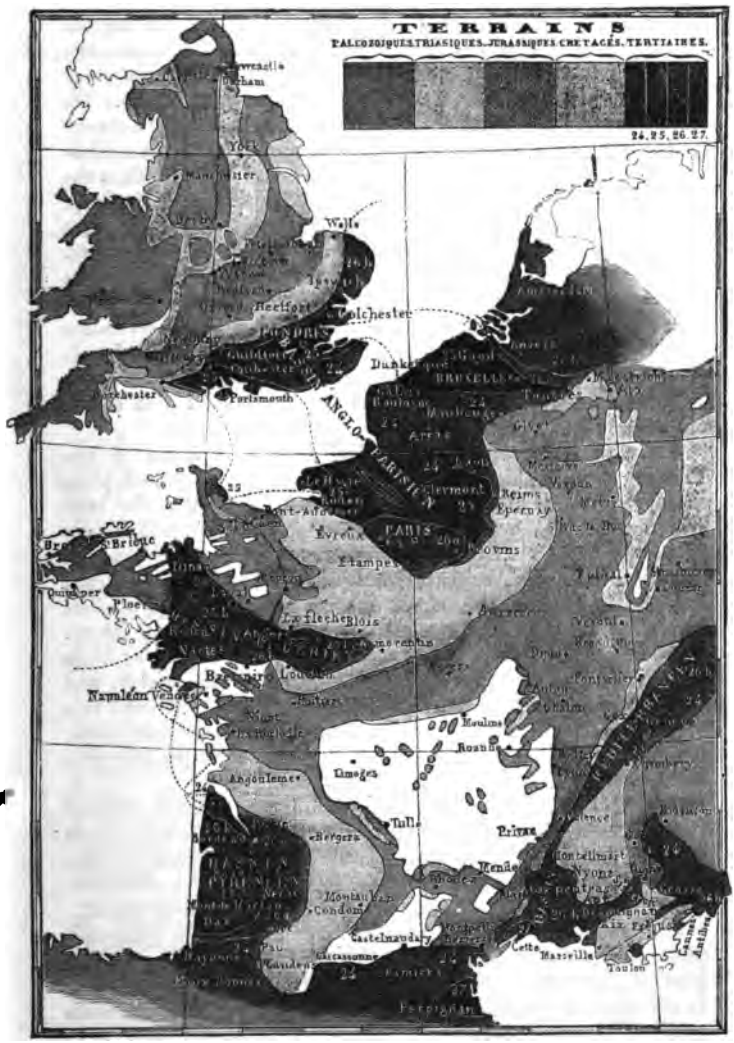


Fig. 181.—Map of France and England in the Tertiary Age. By M. D'Orbigny.

The fourth, to which the name of Ligerian basin has been given, covered part of the western provinces of France, as indicated upon the map (fig. 181).

462. It must not be understood, however, that during the whole continuance of the Tertiary age, or even during any two periods of it, these seas maintained the same circumscription or corresponded exactly with the outlines given in this map. On the contrary, the geological convulsions which took place between period and period, produced such changes of level in the land as completely to derange the outlines of land and water. Thus the Anglo-Parisian basin not only changed its form and limits in different periods, but in one totally disappeared, while in the first periods of the Tertiary age the Ligerian basin had no existence. Previously to the convulsion in which the chain of the Pyrenees was elevated, the Pyrenean basin covered the ground upon which that range afterwards stood, but after their elevation its shores were driven northwards and its dimensions considerably reduced. These changes of the outlines of land and water will, however, be more clearly explained in the account we shall give of the successive periods of this age.

463. The most striking characteristic of the fauna of the Tertiary age, was the extraordinary development which took place among vertebrated animals. It was then indeed that the land was first peopled by those mammifers so remarkable for their proportions and characters, such as the Anthracotheriums, the Palæotheriums, the Anoplotheriums (fig. 182), the Dinotheriums, the Toxodons, the Mastodons, the Smilodons, the Glyptodons (fig. 183), the Megatheriums, the Megalonix, and many others. It was then also that the continents were first peopled by birds which would be pronounced colossal even beside the ostrich, and with salamanders as large as the present crocodile. Around this stupendous fauna was collected a flora on a proportionate scale. The seas were peopled by marine classes in a corresponding proportion, and almost as varied as in our own day.

464. The generic animal forms, peculiar to present tropical climates, being found distributed indifferently in all latitudes, it is inferred that a general tropical temperature, as in former periods, prevailed, and that consequently no isothermal lines or climatological distinctions existed upon the earth until the present period.

465. Numerous indications are also found among the geological phenomena, of the prevalence during this age of those slow and gradual undulations of the earth's crust which are still in progress in the north of Europe and elsewhere, independently of the more violent class of convulsions by which period was divided from period, fauna from fauna, and flora from flora.

FIRST TERTIARY PERIOD.

466. The first Tertiary stage in its mineralogical characters corresponds with the lower part of the Eocene group of Lyell, the Nummulitic formation of Gras and other geologists, the Plastic clay of Dufresnoy, Elie de Beaumont, and Mantell, and the Woolwich sands of Morris.

467. After the general agitation produced by the geological convulsion which closed the Cretaceous age had subsided, a new fauna and flora were called into existence to people and clothe the earth. A generic synopsis of the former is produced in the following table:—

Synopsis of the Animal Kingdom (exclusive of Annulata) during the First Tertiary Period.

		Genera.				
		Total.	Created.	Revived	Extinct.	Characteristic.
Vertebrata.	Mammifers	6	6	0	0	0
	Birds	1	1	0	1	1
	Reptiles	2	0	2	0	0
	Fishes	91	83	8	34	34
Mollusca.	Cephalopods	3	2	1	0	0
	Gastropods	70	34	36	0	0
	Lamellibranchia	35	5	30	1	1
	Brachiopods	2	0	2	0	0
	Bryozoa	10	0	10	1	0
Radiata.	Echinodermata	23	13	10	4	3
	Polyparia	17	8	9	3	1
	Foraminifera	8	3	5	0	0
	Amorphozoa	1	0	1	1	0
		269	155	114	45	40

With the addition of one genera of Crustacea (squilla), the total summary of the generic forms of animal life in this period will then be 270, of which 156 were now first created, and the remaining 114 revived from former periods.

468. This period was remarkable for the great development of fishes, of which 83 new genera were created. Of the Mollusca, the Gastropods were most developed, 34 new genera having appeared. The total number of species of Mollusca and Radiata described in this period amounts to 678, which, however numerous, are inferior in number to the same divisions in some former periods. Before the Tertiary age, some few traces of the existence of Mammifers were found, but with the exception of a few isolated bones, such traces everywhere consisted of foot-tracks.

469. The commencement of the Tertiary age was, however, more especially signalised by a prodigious accession to this highest

branch of the animal kingdom, six genera being created and named as follows:—

Anthracotherium, a genera of Pachydermatous animals, found in the lignite or brown coal in Italy, the name being a Greek compound, signifying *coal beast*.

Lophiodon, another Pachydermatous animal, allied to the Rhinoceros or Tapir, taking its name from a Greek compound, signifying *teeth*, formed like the hairs of a *mane*.

Lutra, a generic form of which the otter is the type.

Canis, a generic form of which the dog is the type.

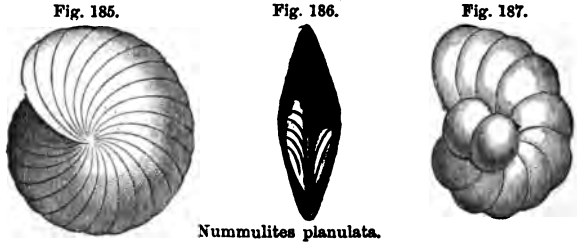
Viverra, a generic form of which the ferret is the type.

Sciurus, a generic form of which the squirrel is the type.

470. The seas were enriched with a great number of animals hitherto unknown. The shores were animated by innumerable fishes, including many Pleuronectoids, or flat fish, which now appeared for the first time (fig. 184).

471. Among the multitude of Mollusca new to the world at this epoch, may be mentioned the Beloptera, Oliva, Tritons, Terebratulæ, &c. The Zoophytes and Foraminifera abounded, compensating by their prodigious numbers for the minuteness of their dimensions; but the class from which the period took its most prominent character was that of the Nummulites, an animal of a round flat form, resembling that of a coin, from which the name of the class is taken (figs. 185, 186, 187). These animals are technically described as chambered spiral univalve shells.

Fig. 185. Fig. 186. Fig. 187.



Nummulites planulata.

These Nummulites lived far from the coast, and their shells were deposited in layers of prodigious thickness upon the deepest bottoms of the seas.

472. At subsequent periods geological convulsions occurred, by which the conchiferous strata thus formed were forced upwards, so as to form mountain ranges. An example of such chains is presented in the Pyrenees, where entire mountains are found consisting of little else than the fossilised remains of these minute animals. It is a striking fact also, that it was of like materials that the Pyramids of Egypt were built.

473. The great duration of this first Tertiary period may be judged from the fact, that these nummulitic strata have in some localities a thickness of several hundred yards. The marine flora of this period consisted chiefly of Cryptogamous Amphigenes, Algæ, and monocotyledonous Naiads.

474. The terrestrial flora consisted of Cryptogamous Acrogenes, such as Hepaticæ, ferns, Equisetaceæ or mares' tails, Characeæ, Palms, Conifers, and Taxineæ.

475. In comparing the geography of this period with that of the preceding, it will be seen that, while at some parts the seas are limited by the same shores, at others their outline is completely changed. Upon the northern and southern borders of the Anglo-Parisian basin, the shores lie within those of the Cretaceous age, leaving a band of ground, previously submerged, uncovered. On the south, the shores have retired still further, no traces of the deposits of this stage being found beyond the line which would pass through Montereau, Melun, Paris, Houdan, and Louviers. This basin extended in England, in an irregular direction S.W. and N.E., from Dorchester to Wells, passing through Dorsetshire, Wiltshire, Surrey, Berkshire, and Hertfordshire, in a direction which probably extended much further to the north over the ground now covered by the German Ocean.

476. In the Pyrenean basin the northern limits of the sea were nearly the same as in the Cretaceous period. It extended probably from the Atlantic Ocean to the Mediterranean, covering all the space upon which the Pyrenees now stand as well as part of Spain.

477. In the Mediterranean basin the sea entirely changed its place: Provence, which it formerly covered, was now occupied by fresh-water lakes, but the sea appeared above Grasse, in the department of the Var; its western shore extended W.N.W. to Castellane, and seemed to follow the line now occupied by the chain of the Alps to Annecy, and beyond that to Glaris.

478. Beyond these limits this sea extended to the east, over Sardinia, Italy, the Tyrol, part of Switzerland, and communicated probably with Egypt, the Crimea, the Caucasus, and from the slopes of the Ural to India. Corresponding changes took place on the land, a fresh-water lake existed at Rilly la Montaigne. On the north of the Pyrenean basin the land was uninterrupted from the Ocean to the Mediterranean.

479. A fresh-water lake covered the part of Provence between Orgon, Martignes, and Aix. These and other details may be easily followed on M. d'Orbigny's map (fig. 181), where the seas of this period are distinguished by the shading number 24.

480. The changes which took place in the outlines of land and water in consequence of the convulsion which closed the Cretaceous

age, and which preceded the first Tertiary period, will be clearly perceived by comparing those parts of the map (fig. 181), which we have here indicated, with the parts of the map (fig. 172, numbered 22.)

SECOND TERTIARY PERIOD.

481. The animal and vegetable world of the first period was swept away by the convulsion produced by the elevation of the chain of the Pyrenees, which was attended with a general perturbation of the whole surface of the globe. The date of this convulsion is identified with the first Tertiary period by the fact of the nummulitic strata which were deposited during that period being found dislocated along the entire extent of the Pyrenean range. The same dislocation elevated the tract of Bray in France and the country round Boulogne, both of which were submerged by the Anglo-Parisian sea. Parts of Surrey and Sussex in England, including the Wealden, were raised at the same time.

The second Tertiary stage includes the London clay of English geologists, the fresh-water and marine formation of Morris, a part of the eocene of Lyell, the blue clay of Bracklesham, the arenaceous limestone of Bognor of Mantell, and the calcareo-arenaceous system of Galeotti.

482. The following is the generic synopsis of this period:

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Second Tertiary Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	21	17	4	8	7
	Birds	11	10	1	2	2
	Reptiles	6	2	4	0	0
	Fishes	39	20	19	14	10
Molluscа.	Cephalopods	4	0	4	1	0
	Gastropods	78	7	71	6	1
	Lamellibranchia	57	9	48	3	3
	Brachiopods	2	0	2	0	0
	Bryozoa	14	1	13	2	1
Radiata	Echinodermata	13	5	13	6	3
	Polyparia	45	28	17	20	16
	Foraminifera	31	13	18	5	8
	Amorphozoa	1	0	1	0	0
		327	112	215	67	46

With the addition of five genera of Crustacea, the total number of genera ascertained to have existed in this period was, therefore, 332, of which 116 appeared for the first time in the world.

483. Independently of several hundred species of Vertebrata and Annulata, the fauna of this period included 1576 species of Mollusca and Radiata, which have been enumerated and described by D'Orbigny.

484. A great number of new animals abounded in the seas, the chief part of which consisted of new genera of fishes and Polyparia or Zoophytes. It was in this period that the class of Cetacea or marine mammifers first appeared in the genera of the Dolphin and the Balænodon. Among the Crustacea the generic forms of crabs were first presented.

485. Of the Zoophytes and Foraminifera, the Miliolæ, characterised by its multilocular shell, and taking its name from *milium*, the Latin word for millet seed, prevailed in numbers so enormous, as to form those strata of stone of which nearly the whole of the city of Paris is built. It is a curious circumstance, therefore, that one of the greatest cities of the world should owe its fabrication to the original industry of minute animals which lived countless ages before the creation of man. The prodigious multitude of these minute beings, which must have existed to produce the quarries of Paris alone, not to mention similar ones which exist elsewhere, may be imagined when it is stated that, taking into account the weight of these shells, it has been calculated that a cubic inch of stone must be composed of not less than two thousand millions of them.

486. The marine flora of this period was generically similar to that of the last, differing, however, altogether in the species. Numerous land animals appeared for the first time, among which may be mentioned the following,—*mammifers*, apes and bats; *birds* (fig. 188), predaceous climbers and gallinaceous; *reptiles*,

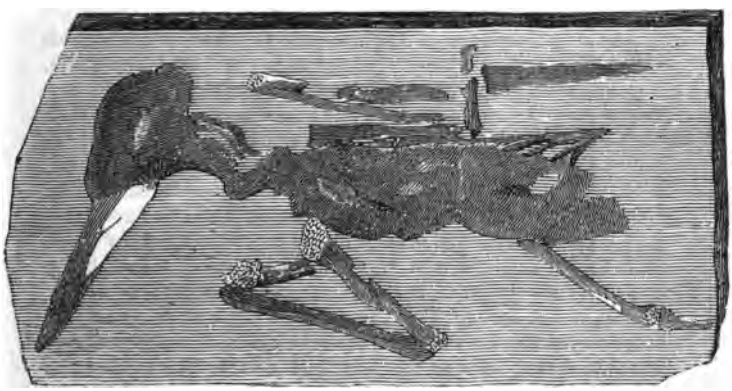


Fig. 188.—Fossil in the Gypsum of Montmartre.

serpents. The forests of France and England abounded in generic forms, of which baboons, rattlesnakes, and opossums are the living types.

The plains nourished Pachydermatous animals, called Paleotherium, Anaplotherium, &c. (fig. 189).

Fig. 189.—Common Anaplotherium.

487. The gigantic saurians of former periods had altogether disappeared in the Cretaceous age, but a large race of crocodiles and land and sea tortoises succeeded them. The Belemnites and their chambered shells had disappeared from the seas, the Nautilus alone remaining.

The cicadeæ totally disappeared from the flora, and new conifers, with dicotyledonous plants and palms, appeared in the centre of Europe,—plants which at present have receded into Africa, showing that the mean temperature of the continent then corresponded to that which at present prevails in Lower Egypt.

488. The outlines of land and water underwent important changes in consequence of the convulsions which preceded this period. The Anglo-Parisian basin was divided into two gulfs, completely separated, by a tract passing through its middle in a direction nearly east and west. The two separate basins thus formed are marked on the map by the shading 25. The northern basin in France covered part of Belgium, including Brussels and Ghent, with an angle of France, which included Dunkirk. In England it included London and the mouths of the Thames.

The southern basin was limited in France on the north by Laon, and extended east and west between Havre and Epernay, being bounded by an irregular line. It may be considered as highly probable, if not certain, that the northern gulfs in England and France communicated with each other by a tract of water included within the dotted lines on the map, and that in like manner the southern gulfs were united by a tract of water extending from Havre to the Isle of Wight.

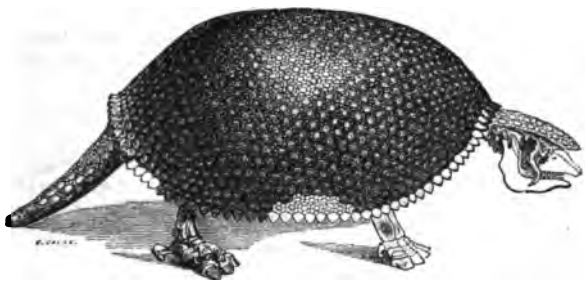


Fig. 183.—GLYPTODON CLAVIPES.

THE PRE-ADAMITE EARTH.

CHAPTER IX.

489—490. Great change in the Pyrenean and Mediterranean basins.—491. Land and water in the United States.—492. Effect of the elevation of the Pyrenees.—493. General prevalence of tropical climate.—494. Great change in the Mediterranean basin.—495. Sketch of part of Western Europe by Elie de Beaumont. THIRD TERTIARY PERIOD. 496. Mineral character of the stage.—497. Convulsion which preceded the period.—498. Outlines of land and water.—499. Marine fauna and specific forms of Mollusca and Radiata. FOURTH TERTIARY PERIOD. 500. Mineral character of the stage.—501. Synopsis of animal kingdom.—502. Specific forms of Mollusca and Radiata.—503. Convulsion which preceded the period—Disappearance of Anglo-Parisian sea—Ligerian basin.—504. Pyrenean basin.—505. Marine fauna.—506. Enormous increase of land animals, including the generic forms of the bear, the cat, the weasel, the seal, the mouse, the beaver, the rhinoceros, the tapir, and the stag.—507. Great increase of reptiles and fishes, including snakes, frogs, salamanders, perch, herring, and carp.—508. Flora, including the generic forms of various conifers; birch, alder, oak, beech, elm, fig, plantain, poplar, laurel, sloe-tree, maple, red jasmin, madder.—509. Uniform tropical climate. FIFTH TERTIARY PERIOD. 510. Mineral character of the stage.—511. Synopsis of the animal kingdom.—512. Outlines of land and water.—513. Elevation of the Western Alps—its effects.—514. Map of France by M. Elie de Beaumont.—515. Marine animals, including the generic forms of gudgeon, pike, loach, blay, and tench.—516. Terrestrial fauna including the megatherium, megalonyx, mylodon, and mastodon, and the generic forms of the elephant, hippopotamus, camel, giraffe, and stag.—517. Birds of the generic forms of the vulture, eagle, swallow, woodpecker, chat, anabate, lark, mothhunter, cuckoo, parrot, pheasant, common fowl,

guinea fowl, flamingo, horned owl, rail, corncrake, goose, loon, duck, gull, &c.—518. Fossil salamander of Œningen.—519. Flora, including generic forms of liquidamber, willow, myrtle, anemone, plum-tree, magnolia, holly, rhododendron, and azalea.—520. Large numbers of Mammifers. — 521. Bone caves—cave of Gaylenreuth.—522. Retrospect. — 523. Was creation at each period simultaneous. — 524. Proofs in the affirmative.—525. Was there a progressively increasing perfection of organisation.—526. Number of orders in the respective strata.—527. Of genera in the orders.—528. Increase and decrease of genera in the orders.—529. Orders in which the decrease took place.—530. Orders of fishes.

489. GREATER changes still were produced, as indeed might be expected, in the Pyrenean basin. While its northern shores remained nearly the same, the southern limits were altogether changed. The sea, which in the preceding period covered all the ground upon which the Pyrenees stand, extending over part of Spain, was now driven back to the north, and occupied only a very small basin near Bordeaux, marked 25 on the map.

490. The same cause produced a considerable change in the shores of the Mediterranean basin, which no longer communicated with the Pyrenean basin, its western shores being driven back towards the east. It is probable that its western shores commenced near Nice, passing near Faudon and St. Bonnet, the site of the High Alps, from which, however, that chain had not yet arisen. From thence the shores of this sea were continued to Bex in Switzerland, where all traces of them are lost.

491. During this period, a considerable tract of the United States, extending from 31° to 39° lat., which had been raised above the waters since the end of the Cretaceous age, became submerged, so that the sea probably extended without interruption from Paris to the southern part of North America.

492. Corresponding changes took place in the land by the elevation of the chain of the Pyrenees, which presented a barrier to the progress of the ocean, and which left high and dry not only the mountain range itself, but also the interval included between that and the central plateau of France, so that Languedoc and Provence, and the surrounding country, formed one great continent.

493. The appearance of marine species identical with those deposited in the Anglo-Parisian basin in the seas by which the southern states of America were submerged, and the discovery of apes, rattlesnakes, and generic forms of marine animals and plants, proper to warm climates in all parts of Europe, and in the Isle of Sheppey, in England, prove that, at this epoch,

the temperature of the present equatorial regions prevailed generally throughout Europe.

494. During this period, the Mediterranean basin was reduced to some small patches of water, which appeared in the Savoy, and in the region upon which the French Alps now stand. These are marked upon the map by the number 25.

495. Before the geology of Western Europe, in relation to this age, was submitted to the elaborate analysis of M. D'Orbigny, from which the details explained above have resulted, M. Élie de Beaumont published a map of its geography during this period, of which we give a reduction in fig. 190.

It will be seen that, according to this, the Anglo-Parisian

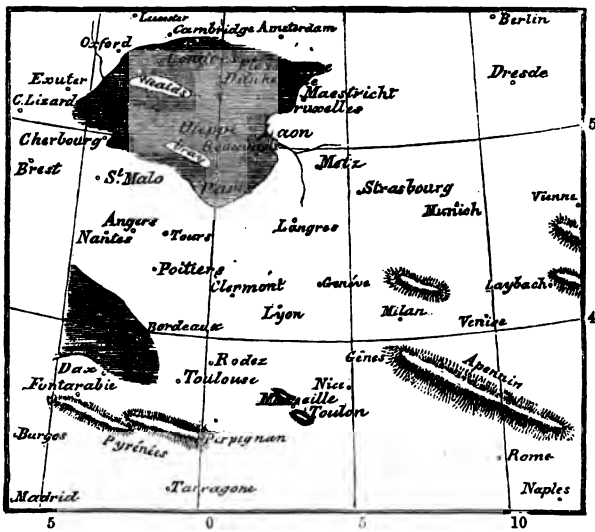


Fig. 190.—Map of Western Europe during the Second Tertiary Period.

basin was not inferred to be divided into two separate gulfs, as above described, but an insular tract was supposed to be formed around the country of Bray in France, and another around the Wealden in England.

The basin was assumed by M. Elie de Beaumont to extend between Paris and the Lizard Point, Cambridge and Maestricht. The Pyrenean basin is represented as limited between Bordeaux and Dax. It is probable, however, that the more recent

geological researches in these regions have supplied data which have rendered the map of M. D'Orbigny the more exact.

THIRD TERTIARY PERIOD.

496. The strata deposited during this period, according to M. D'Orbigny, correspond with the middle *terrain tertiaire* and *grès de Fontainebleau* of MM. Dufresnoy and Élie de Beaumont, the Tongrian, Rupelian, and Bolderberg strata of M. Dumont, the Molasse of Switzerland, the Faluns bleus of M. Grataloup, and, in fine, with the fifth group of M. D'Archiac.

497. The second Tertiary period was closed by the convulsion which raised the system of Corsica and Sardinia of M. Elie de Beaumont. Upon the re-establishment of tranquillity, a new fauna was created, consisting of 428 species of Mollusca and Radiata, independently of the vertebrated and annulated classes.

498. The outlines of land and sea underwent several changes, the results of which will be seen on the map, the seas during this period being indicated by the shading marked 26*a*, fig. 181. The Paris basin was limited to a space round Paris, between Provins and Evreux, east and west. The Pyrenean basin covered the space similarly indicated and shaded, a tract of dry land, however, remaining to the N.W. of Blay. In Belgium, the seas advanced to the N.E., as far as Limbourg, in the neighbourhood of Maestricht.

499. The marine animals of this period, though generically identical with those of the succeeding one, were, nevertheless, specifically distinguished from them. This distinction has not, however, been clearly indicated, except in the case of the Mollusca and Radiata, 428 species of which M. D'Orbigny has identified with the deposits of this period. The flora included nearly the same generic forms as in the preceding epoch.

FOURTH TERTIARY PERIOD.

500. The strata deposited in this period, according to D'Orbigny, include part of the middle Tertiary and Falunian of MM. Dufresnoy and De Beaumont, the Molasse, Falunian and Crag of M. Cordier, the superior order of Conybeare, and the Miocene and Suffolk and Norfolk Crag of Sir C. Lyell.

501. The following is the generic summary of the fauna, which, however, includes a certain number of genera of the Vertebrates peculiar to the third stage.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Fourth Tertiary Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	57	47	10	27	23
	Birds	7	4	3	0	0
	Reptiles	13	7	6	3	2
	Fishes	28	7	21	1	1
Mollusca.	Cephalopods	3	1	2	2	1
	Gastropods	97	20	77	1	1
	Lamellibranchia	64	6	58	2	0
	Brachiopods	8	1	7	0	0
	Bryozoa	20	5	15	3	2
Radiata.	Echinodermata	23	6	17	2	1
	Polyparia	45	15	30	16	6
	Foraminifera	42	14	28	3	2
	Amorphozoa	1	0	1	0	0
		408	133	275	60	39

With the addition of fourteen genera of Crustacea, it appears, therefore, that this fauna consisted of 422 genera, of which 133 were new, and the remainder revived from preceding periods.

502. Independently of several hundred species of Vertebrata and Annulata, 2754 species of Mollusca and Radiata proper to this period have been catalogued and described.*

503. The third period was closed, and the present preceded by the dislocation which produced the system of the Isle of Wight, of the Tatra, of the Rilodagh, and of Mount Hæmus, as shown by M. Élie de Beaumont. After the re-establishment of tranquillity, the outlines of sea and land had undergone considerable changes. The water by which the Anglo-Parisian basin had never ceased to be submerged since the Triassic age, retired, and left all that region dry land. A new sea, however, was formed in the west of France, to which the name of the Ligerian basin has been given by M. D'Orbigny, and the limits of which are indicated on the map by the shading marked 26 *b*, fig. 181. The deposit left by this basin was, however, by a subsequent convulsion, broken into patches, so that, at the present time, it does not present one continuous stratum.

504. The Pyrenean basin was contracted within the limits marked on the map 26 *b*, fig. 181. The Mediterranean basin under-

* Prodrome D'Orbigny, vol. iii. p. 25 *et seq.*

went a complete change of form. It now submerged a vast surface, which was previously dry land, included between Montpelier and a tract to the west of Marseilles, extending on the north into the departments of the Gard and the Drôme. It extended also to the N.E. as far as the tract upon which the Lower Alps stand. Another arm of this sea turned to the N.N.E., covering part of Savoy and Switzerland, and extending probably to Vienna and still further in that direction. Thus three seas were still found in the west of Europe—the Ligerian basin taking the place of the Anglo-Parisian basin. In England, the Anglo-Parisian basin was limited to Suffolk and Norfolk, where it covered the whole coast, and it probably extended from thence across the Channel into Belgium, covering the land around Antwerp.

505. The seas during this period were peopled by numerous animals unknown to any anterior epoch. Not less than 89 marine genera appeared for the first time, among which the Gastropods amounted to 20, and the Foraminifera to 15. Among the Crustacea which now first appeared in the seas, were included the generic forms of which the Hermit crab and the Lobster are types.

506. But it was by its land animals that this period, compared with all former ones, was more especially remarkable. It appears by the table, that of the 57 genera of Mammifers ascertained to have lived in this period, 47 had never before existed. Of these genera a great number, remarkable either for their magnitude or their peculiar forms, have become extinct, among which may be mentioned Palæomys, Macrotherium, Dinotherium, fig. 191, Toxodon, and Mastodon. Among the forms which

Fig. 191.—Dinotherium giganteum.

have survived, we find living types in the bear, the cat, the weasel, the seal, the mouse, the beaver, the rhinoceros, the tapir, and the stag.

507. Among the reptiles which now appeared for the first time were generic forms, whose types are snakes, frogs, and salamanders, and among the fishes, those of which the types are the perch, the herring, and the carp, fig. 192.

508. The flora of this period included Amphigamous cryptogamia (Algæ and mushrooms), Acrogenous cryptogamia (Mosses and ferns), Monocotyledons, Dicotyledonous gymnosperms (numerous conifers), Dicotyledonous angiosperms (birch, alder, oak, beech, elm, fig, plantain, poplar, laurel, rose-tree, acacia, sumach, nut-tree, sloe-tree, maple, red-jasmine, madder.)

509. The presence in all the European seas of species, both

Fig. 192.—Lebias Cephalotes. Cyprin (Carp).

animal and vegetable, now peculiar to the Torrid Zone, proves that there prevailed, in this period as in the former, in France, England, and Germany, and probably in all other parts of the globe, a uniform temperature similar to that which now characterises the tropics. Climatological lines had not therefore yet existed.

FIFTH TERTIARY PERIOD.

510. The strata deposited in this period corresponded with the older Pleiocene of Sir C. Lyell.

511. The following is a generic synopsis of the fauna, with the xception of three genera of Crustacea.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Fifth Tertiary Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	72	42	30	33	25
	Birds	29	26	3	1	1
	Reptiles	14	7	7	5	5
	Fishes	16	8	8	3	1
Mollusca.	Cephalopods	1	1	0	0	0
	Gastropods	64	2	62	0	0
	Lamellibranchia	46	2	44	0	0
	Brachiopods	4	0	4	0	0
	Bryozoa	8	0	8	1	0
Radiata.	Echinodermata	14	0	14	4	0
	Polyparia	8	0	8	3	0
	Foraminifera	29	3	26	1	0
	Amorphozoa	0	0	0	0	0
		305	91	214	51	32

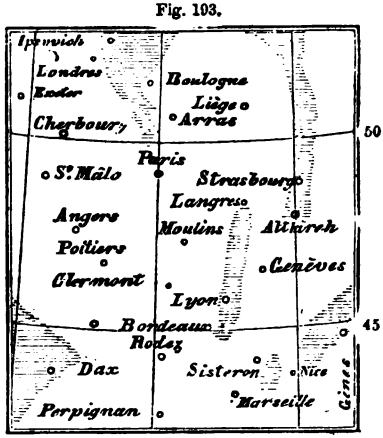
Of the Mollusca and Annulata alone 606 species have been catalogued and described. The fourth or Falunian period, as M. D'Orbigny has named it, was closed, and the fifth or sub-Apennine preceded by the geological convulsion, in which the Western Alps burst through the terrestrial crust and were elevated to their present relief.

512. The seas had again completely changed their beds in Europe, and especially in France. The three seas, which in the preceding period submerged the Ligerian, Pyrenean, and Mediterranean basins were now completely dried up, none remaining except small patches of water on the borders of the Mediterranean, in the departments, in the East Pyrenees, and in the Herault, near Montpelier. It appears, therefore, that in France land and water now assumed very nearly the forms which they possess at present, but in Piedmont the province of Asti was still submerged, as well as part of Italy, a tract round Vienna, and a great part of Eastern Europe.

513. Corresponding changes took place in the land. Switzerland, Savoy, the French departments of the Jura, the Ain, the Isère, the Higher Alps, the Lower Alps, the Drôme, Vaucluse, and the Bouches du Rhône, which had been severally to a greater or lesser extent submerged, during the Jurassic and Cretaceous ages, and during the previous periods of the Tertiary age, were now raised above the waters, and formed part of the general continent.

514. Although the western part of Europe, including France and part of Switzerland, were no longer submerged by the sea, sheets of fresh water existed in certain places. Thus, according to M. Beudant, a lake existed in France, extending north and south from Langres to Valence, fig. 193, and a similar one in Provence, between Sisteron and Verdon. The channel of Alsace, also, according to this geologist, still communicated with the ocean, and that of Piedmont, commencing from Nice and Genoa, was connected with the seas which washed the Apennines.

Fig. 193.



515. The seas of this period were peopled with the same generic forms as in the preceding, with the addition, however, of some new genera of fishes, such as the Gobius (gudgeon), Esox (pike), Cobitis (loach), Aspius (blay), and Tinca (tench).

516. The terrestrial fauna included a vast variety of forms, remarkable by their proportions and characters. Among the Mammifers were the Glyptodon, fig. 183, Megatherium, fig. 194, Megalonyx, Mylodon, fig. 195, and Mastodon, all of which are extinct. Among the genera which have since reappeared under other specific forms were elephants, fig. 196, hippopotami, camels, giraffes, horses, stags, fig. 197, p. 145, armadilloes, fig. 198, and sloths.

517. Among the birds were included genera of which the following are types, the vulture, eagle, swallow, woodpecker, chat, annabate, lark, moth-hunter, cuckoo, parrot, pheasant, common fowl, guinea-fowl, flamingo, horned-owl (hibou), rail, corncrake, goose, loon, duck, gull, grabe.

518. Among the reptiles of this period must especially be noticed the celebrated gigantic Salamander, fig. 199, found in the lacustrine limestone of Œningen. The first specimen of this fossil which was discovered obtained much notoriety from having been described as a human skeleton, under the fanciful name of *Homo diluvii testis*—a man who was witness of the deluge. Cuvier examined this specimen, and ascertained it to be the remains of a species of aquatic salamander. Other specimens of

the same fossil have been found which measured nearly five feet in length.

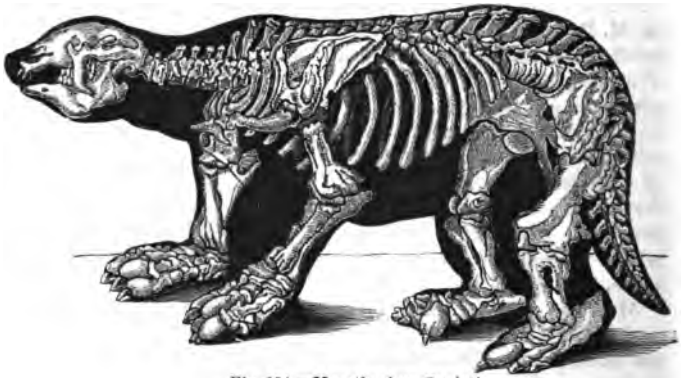


Fig. 194.—Megatherium Cuvieri.

519. To nourish the enormous herbivorous animals, which covered the land in such numbers from Italy to the Frozen

Fig. 195.—Mylodon robustus.

Ocean, and which at present are found only in those tropical

regions clothed with the richest vegetation, nature presented everywhere during this period the most varied and exuberant flora, which included nearly all the vegetable forms enumerated in

Fig. 196.—Elephas primigenius, or the Mammoth, an animal of the Tertiary Age.

the preceding period, with the addition of numerous others, among which may be mentioned liquidamber, willow, myrtle, anemone, plum-tree, magnolia, holly, rhododendron, azalea, &c.

520. It is to this geological period, that the prodigious numbers of Mammifers found in the strata of the Pampas of Buenos Ayres, and in the caves which are scattered in such vast numbers over the continents of Europe and America, and even in Australia, are ascribed. In the Brazils are numerous bone-caverns, which contain genera still inhabiting the South American continent, though differing from the living species. It is worthy of especial notice, observes Dr. Mantell, that the bones of a species of horse

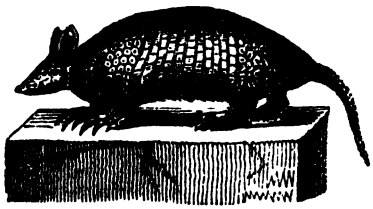


Fig. 198.—Armadillo.

occur in these accumulations, for when the Spaniards invaded the country, horses were wholly unknown to the inhabitants, who, on seeing a Spaniard on horseback, supposed that the man and horse composed a single animal. It is a marvellous event in the history of the world, that a native species should have disappeared, and should have been succeeded in after ages by countless herds of the same genus introduced by man's intervention.

521. One of the first bone-caves which attracted attention was that of Gaylenreuth in Franconia, a section of which is shown in fig. 200.

The entrance of this cave, about seven feet in height, is placed on the face of a perpendicular rock, and leads to a series of chambers from fifteen to twenty feet in height, and several hundred feet in extent, in a deep chasm. The cavern is perfectly dark, and the icicles and pillars of stalactite reflected by the torches present a highly picturesque effect. The floor is literally paved with bones and fossil teeth, and the pillars and corbels of stalactite also contain osseous remains. Cuvier showed that three-fourths of the remains in this and like caverns were those of bears, the remainder consisting of bones of hyenas, tigers, wolves, foxes, gluttons, weasels, and other Carnivora.

Fig. 199.—Fossil Salamander (Andrias Scheuchzeri).

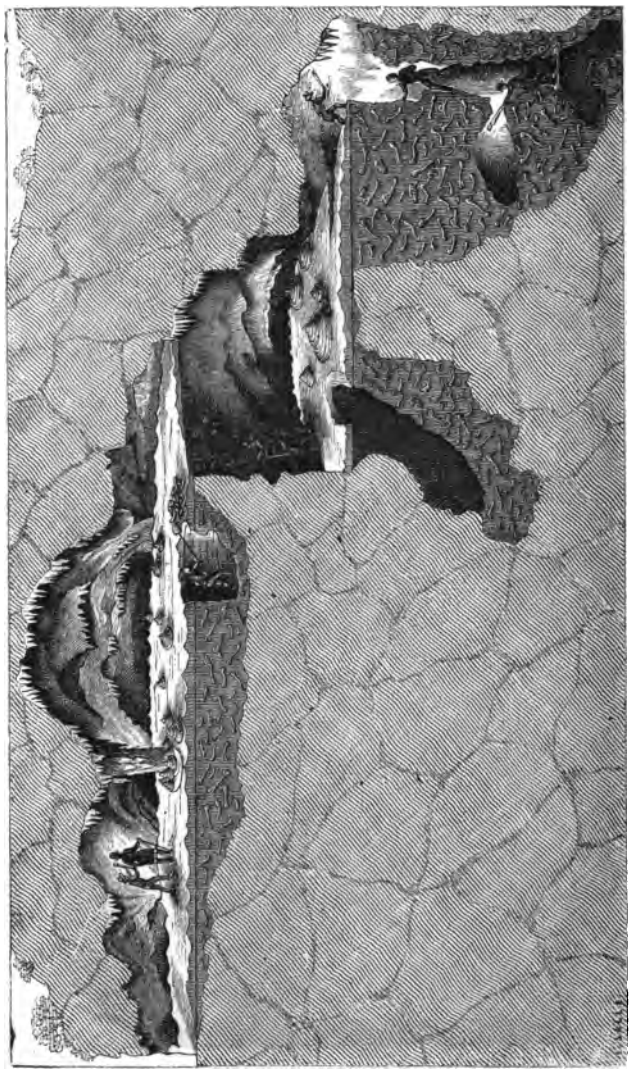


Fig. 200.—Section of the Bone Cavern of Gaylenreuth, Franconia.

RETROSPECT OF THE PRE-ADAMITE AGES.

522. Upon a review of the history of the earth previous to the appearance of the human race and its contemporary fauna and flora, as briefly sketched in the preceding pages, several considerations of high interest respecting the progressive development of organic life upon it present themselves.

Naturalists have grouped the animal world into the 20 classes indicated in the table given in (244), and have subdivided these classes into 77 orders. Each of these 77 orders is again resolved into a certain number of generic forms.

It will be matter of obvious interest to inquire in what manner the author of nature has proceeded in the work of creation, first, in considering each act of creation in itself, and independently of the others; and secondly, in comparing one with another the successive creations described in the preceding pages.

523. Were all the forms of organic life, which existed upon the earth at any one epoch, called simultaneously into being? The habits and economy of animals answer this question. In relation to their modes of nourishment they may be resolved into two classes: the first, herbivora, consisting of those which feed on vegetables; and the second, carnivora, of those which feed either partially or exclusively on other animals.

It is clear, then, that the creation of the vegetable world must, in each case, have either preceded or have been simultaneous with that of the herbivora, since a class of animals could not be created without a provision of a food of suitable quality.

For a like reason the creation of herbivora must either have preceded or been simultaneous with that of carnivora.

524. That all parts of the earth were simultaneously peopled, not only at the first creation which took place upon it, but at all succeeding ones, is proved by the fact that the same animal and vegetable forms are found deposited in the same strata in all parts of the earth. The animal forms, for example, preserved in the Palæozoic strata of Europe are identical with those found in the corresponding formation in all parts of the world, however distant from each other, and the same is true of the Triassic, the Jurassic, and all the other groups of strata.

525. The second question, whether creative power manifested itself by a progressive development of organised forms, may be considered either with relation to orders or generic forms.

Of the seventy-seven orders of animals, an obviously increasing progression of development will be apparent on comparing age with age.

526. The number of orders of which examples are found deposited in the strata are as follows:—

Palæozoic formation	31	Cretaceous	41
Triassic	21	Tertiary	71
Jurassic	41	Existing period	77

These figures show that the orders of animals are in constantly increasing progression. The exception presented by the Triassic group may probably be explained by the want of sufficient observation of its organic remains.

527. This constant increase does not prevail with the genera. In each period each order consisted of a certain definite number of genera. Now, on comparing the number of genera of which each of these orders consisted, from period to period, it will be found that while some continually increased, others having increased up to a certain date, attained their maximum, and then decreased, and that the decrease has continued to the present time.

528. Of the seventy-seven orders, it has been found by comparison of the organic remains of the successive periods, that sixty-three have had a continually increasing number of genera from their first appearance to the present epoch, but that the numbers of the genera of the other fourteen respectively after increasing to a certain period, then decreased, and that this decrease continued.

529. Six of these fourteen orders acquired their greatest generic development in the Palæozoic period. These six consisted of two orders of Fishes, one of Crustacea, two of Mollusca, and one of Radiata.

530. The two orders of Fishes are those denominated by naturalists the *placoids* and the *ganoids*. Of the former the *shark* and the *ray*, and of the latter the *sturgeon*, are living examples.

Fig. 197.—CERVUS MEGACEROS CUVIERI.

THE PRE-ADAMITE EARTH.

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CHAPTER X.

531. Examination of orders.—532. Relative numerical proportion.—533. No progression discoverable in these.—534. Examination of generic development.—535. Similar result.—536. In the Radiata and Mollusca.—537. Annulata.—538. Vertebrata.—539. No progress indicated.—540. Organs of ancient animals.—541. Examination in relation to respiratory organs.—542. Lower divisions.—543. Branchial respiration.—544. No essential change.—545. No progression observable.—546. Tracheal respiration.—547. Pulmonary respiration.—548. Composition of atmosphere unchanged.—549. General

conclusions.—550. Persistence of genera.—551. Useful geological test. **The Contemporaneous Age.**—HUMAN PERIOD. 552. Elevation of the great Alps—total destruction of the fauna and flora of the last period.—553. Great change of form in Europe.—554. Secondary effects — vast rivers and lakes producing alluvial deposits. — 555. Creation of a new fauna and flora.—556. Tabular view of the existing and past animal kingdoms.—557. General inferences from this.—558. Number of species of Mollusca and Radiata, and their distribution.—559. Total number of species.—560. Creation of mankind.—561. First appearance of climatological zones.—562. Unsuccessful attempts to explain the uniform distribution of species in former ages.—563. The formation of downs—littoral deposits and the filling of lagoons and deltas supply chronological data of the present age.—564. Consistency of the Mosaic history with geological facts.—565. The future of the earth.—566. Accordance of the narrative in Genesis with geological facts.—567. Figurative use of the word day in accordance with common custom.—568. The division of the land from the water.—569. The creation of the vegetable world.—570. First creation of marine tribes and birds.—571. A similar order observed in geological phenomena.—572. Creation of Mammifers.—573. Correspondence with the Tertiary age.—574. Creation of the human race in the actual age.—575. Accordance of Scripture with geological discovery.—576. Conclusion.

531. THE order of Crustacea was that of the *Trilobites*, those of the Mollusca the Tentaculiferous Cephalopods, and the Brachiopods; and that of the Radiata the fixed Crinoids. Two had their greatest number of genera in the Jurassic period. These were the *Saurian reptiles* and the *Free Crinoids*. Four had their greatest number in the Cretaceous period, of which two were Mollusca and two Radiata. In five, two had their greatest generic development in the Tertiary period, both being Mammalia, one *Pachydermata*, and the other *Edentata*. The *elephant* is a living example of the former, and the *sloth* of the latter.

From what has been stated, it appears that of the seventy-seven orders of animals, thirty-one were called into existence during the Palæozoic period. These were distributed among the four principal divisions of animal forms, as follows:—

Vertebrata	3
Annulata	11
Mollusca	9
Radiata	8
	31

532. Thus the four principal divisions of animal forms were represented at the first moment of creation, in a relative numerical proportion not very different from that in which they still exist. This result is completely incompatible with a notion which has been long prevalent, that creative power manifested itself by

a gradually increasing degree of organic perfection from one geological period to another, from the first appearance of animal life upon the globe to the human period.

The only facts which have given colour to this supposition, are the lateness of the period at which the Vertebrated animals of the highest order of organisation, Mammifers and Birds, appeared in any considerable numbers upon the globe, and more especially the fact, that the human race did not appear until after the close of the Tertiary age.

533. That the conclusion thus deduced is a premature generalisation, will appear from an examination of the classes and genera which have prevailed, during all the successive ages from the Palæozoic to the human.

If the supposition of progressive improvement in organisation were well founded, it must naturally be expected that in the earliest period of the Palæozoic, the lowest orders only of organisation would appear, and that consequently the Radiata alone would be found there, while on ascending through the succeeding periods of the Triassic, Jurassic, Cretaceous, and Tertiary ages we should find gradually appearing the more perfect orders of Mollusca, Annulata, and Vertebrata. On the contrary, it appears, from what has been stated, that in the Palæozoic age animals of all the orders from the lowest to the highest were created in a proportion not very different from that in which they now exist.

534. It will be interesting, however, to consider the characteristics of the organisation of the genera composing each of the orders existing at each successive period; for although no progressive increase of perfection might be manifested with regard to the *orders*, such progression might nevertheless appear in the *genera* of these orders created from period to period.

535. A due examination, however, of the genera of the several orders existing at each period will show that no such progressive increase of perfection in the organisation has been manifested.

536. Of the Radiata eight orders were called into being in the Palæozoic age, and none of superior organisation in the succeeding ages. Indeed a rigorous examination of the succession of fauna of this division leads to the contrary conclusion, showing that the most perfect prevailed in greatest numbers at the earliest ages.

A similar examination of the division of Mollusca gives a like result, no gradually increasing perfection of organisation being discoverable.

537. In like manner the supposition of progressively improved organisation from age to age would lead us to expect in Annulated animals all the orders of the less perfect organisation in the

first ages, and those of the more perfect in the later ones. As in the former cases, however, the actual results of observation are altogether opposed to this. Of the eleven orders of Annulata called into existence during the Palæozoic age there are three orders of insects—the Coleoptera, Orthoptera, and Neuroptera; one of the Arachnida, four of Crustacea, one of Cirrhipeds, and two of Annalids. Thus, as in the former case, all the classes are fairly represented. But we find further in these classes, among the three orders of Insects and four of Crustacea, the most perfectly organised of each class. We have therefore, in the case of the Annulata, the same results as were obtained in reference to the other two great divisions of the animal kingdom—the most perfectly organised being produced in the earliest ages; and not only was this the case, but they even there obtained their greatest development.

538. Although, as we have already stated, the Vertebrata present striking facts in favour of the supposition of progressive improvement already mentioned, a due examination of all the circumstances attending their gradual development, will show that no real progressive organisation has been manifested in them. If the supposition of progressively improving organisation were well founded, it must be expected that the Vertebrate animals of less complete organisation alone would appear in the Palæozoic age. We find on the contrary among the three orders of Vertebrata which appeared in that age, the Saurian reptiles and the Placoid and Ganoid fishes. Now, although mammifers and birds did not appear, the reptiles which did appear have a superior organisation to other orders which appeared later, such as serpents and Amphibia. The fishes of this epoch also are evidently superior in their organisation to many of the orders which appeared later. Although, therefore, only two of the four classes of the Vertebrata appeared during this age, of these two the most perfect specimens appeared the earliest, in contradiction to the supposition of progressively increasing perfection of organisation.

The Triassic age presented traces of the existence of the order of birds called *Waders*, and of *Chelonian reptiles* (tortoises). It is curious here to find at an epoch so remote in the history of the globe, birds the most perfect of the aerial Vertebrata, and the Chelonian reptiles, the most perfect of their class.

The Jurassic age presented no new orders of Vertebrata. The Cretaceous age presented one order of birds, the Web-footed; two of fishes, the Cycloids and Ctenoids, both less perfect than those of the Palæozoic age.

It was only, therefore, during the Tertiary age that the other

orders of Vertebrata appeared. The orders of birds which appeared at this most recent epoch were not more perfect in their organisation than the waders of the Triassic age, while the orders of reptiles, including the serpents and Amphibia, were certainly the lowest in organisation of this class.

539. It appears, therefore, that of the four classes of Vertebrata, which appeared from the earliest geological age to the present time, two, the reptiles and fishes, instead of proceeding according to the supposition of progressively improving organisation, showed a series of changes of a directly opposite character, the most perfect being the earliest, and the least perfect the most recent; while the class of birds, with reference to their organisation only, and without reference to their number, remained stationary from the Triassic to the actual period.

540. A question of high philosophical interest arises in reference to the progressive animalisation of the globe, which admits of solution by a due examination of the organic remains deposited in the strata of the earth. This question is that of determining if the various organs of the most ancient animals have remained the same from the commencement of the world, or if they have been modified in consequence of the changes which may have taken place in the external conditions of their existence.

541. Of all the organs, those of respiration are most intimately connected with this question. The several modes of animal respiration are as follows:—

1. Cutaneous respiration, made by the whole surface of the body, and not by any special organ appropriated to that function.
2. Aquatic respiration, made by means of branchia, or gills; a special organ adapted to disengage the oxygen of the air from the water and appropriate it to the vital functions.
3. Tracheal respiration, with which animals are endowed which live in the atmosphere, and appropriate its oxygen to the vital functions by means of tracheæ.
4. Pulmonary respiration, which is performed by lungs, as in the case of Mammalia generally.

Marine animals respire either without any special organ and by means of the whole surface of their bodies, or by branchia (gills).

542. The animals which respire without any special organ, are those of the lowest degree of organisation. Of these all the four classes of Echinodermata, Polyparia, Foraminifera, and Amorphozoa, appeared on the earth in the Palæozoic age in various degrees of perfection. We have therefore here, in the first epoch of creation, all the forms of cutaneous respiration.

543. The animals which have aquatic respiration by means of

branchia (gills), include nearly all the Mollusca; among the Annulata they include the Crustacea, the Annalids, and the Cirrhipeds; and among the Vertebrata, all the fishes. We find all these represented in the Palæozoic age; and, on ascending from age to age, no modification of the respiratory apparatus is manifested. The living species which have branchial respiration belong to the same class as those which exercised like functions during the Palæozoic age.

544. All these circumstances lead, therefore, to the conclusion that the external conditions in which animals exist have undergone no essential change since the Palæozoic age, inasmuch as the organs of respiration have remained the same, a conclusion which is still further confirmed when, descending from the orders, the genera are examined.

545. In fine, to the question whether the marine animals have undergone any change in their structure since the first animalisation of the globe, or if they have greatly improved in their organisation, we may answer without hesitation by an absolute negative; for these primitive genera, or those most closely allied to them, which still represent them on the earth, prove that they had from the first the organic characters which they still preserve—that they have undergone no gradual improvement in organisation—that the medium in which they lived at the earliest epoch of the creation was the same as at present—that, therefore, no great change has taken place as to the conditions of vitality of these beings, and that the seas in which they then existed are essentially similar to those which they now inhabit.

546. All the terrestrial animals, whether of land or water, which breathe otherwise then by branchia, belong to the two classes which breathe either by trachea or lungs.

Less perfect than pulmonary, tracheal respiration is peculiar to the class of insects and some Arachnida. We find this function perfectly represented in the animals of the Palæozoic epoch. As has been already stated, Coleoptera, Orthoptera, and Neuroptera, all of tracheal respiration, have been discovered in the Palæozoic strata. As these insects belong to the same or analogous genera with those which now exist, we must assume that they were endowed with the same respiratory organs. We arrive, therefore, at the conclusion, as well for terrestrial animals which breathe by trachea, as for marine animals, that the respiratory organs have not undergone any progressive improvement, and that this class in the cradle of nature was what it still is; in fine, that the medium of its terrestrial existence has always been the same, since the first animalisation of the globe to the present time.

547. Pulmonary respiration prevails in three of the principal

divisions of the animal kingdom, the Vertebrata, Annulata, and the Mollusca.

The Annulata of early geological epochs, which had pulmonary respiration, belonged to the order of Arachnida. We find, in the Carboniferous strata, one of the Palæozoic group, the remains of an Arachnid (281, fig. 143), already mentioned, closely allied to the scorpion, which it is impossible to doubt had the same organisation as scorpions of the present day, and must, therefore, have lived under like conditions of animal existence.

548. Considered in relation to their geological date, Vertebrata breathing by true lungs are found during the Palæozoic age in the form of Saurians, the most perfect of reptiles. During the Triassic age tortoises and birds appear, which of all animals have the pulmonary system the most developed. It must, therefore, be inferred, that at these remote epochs, the medium in which birds and reptiles breathing the air by lungs lived, was little if at all different from the medium in which similar classes now live, which leads to the conclusion that, at this early period in the history of the globe, the composition of the atmosphere must have been nearly the same as at present.

549. All these considerations lead to the following general conclusions:—

First. If the supposition of a gradually increasing perfection of organisation were admitted, we ought to find all the animals endowed with mere cutaneous respiration in the first stages of the world, and the others, proceeding successively from age to age, endowed with branchial, tracheal, and pulmonary respiration, whereas, on the contrary, we find in the very first epoch of the animalisation of the globe, all the modes of respiration manifested at once—a conclusion entirely at variance with the supposition of progressively improving organisation.

Secondly. Whether we compare together the increasing or decreasing development of zoological forms, or the dates of the appearance of the orders of animals with the perfection of their organs; or take for the basis of our comparative researches the physiological conclusion deduced from the mode of respiration by animals, we uniformly arrive at the same negative results relatively to the supposition of progressive improvement of animal organisation. We must, therefore, accept it as proved, that no such progressive improvement has existed.

Thirdly. No appreciable modification being found in the organs of respiration of animals from the most ancient epoch to the present, a great number of genera having always existed with the same characters since the first animalisation of the globe, it must be inferred that the vital elements have not changed, and that

the media in which animals existed, whether it be air or water, have remained the same both on land and sea.

Fourthly. The media of existence being always the same, no change in these media can be adduced as a cause for the successive extinctions and reproductions of the fauna of the earth, which have been manifested by geological phenomena as taking place during the successive geological periods, a conclusion of immense importance in the history of the globe.

Fifthly. All the researches which have been made in the fossil fauna, deposited in the strata of the earth, lead to a conclusion of high geological importance, that, until the epoch which immediately preceded the appearance of the human race and its contemporaneous tribes upon the globe, all that part of the earth which has undergone a close and accurate geological survey, including France, England, Germany, Italy, Switzerland, Spain, Portugal, part of Russia, and the adjacent seas, were inhabited by a fauna altogether tropical, and such as is at present found only under the torrid zone. We are forced, therefore, to the conclusion that, until the present period, the isothermal zones now observed had no existence.

550. Of 1473 fossil genera hitherto discovered, 16 only are found to exist in all the stages without exception. The remaining 1457 are distributed in different proportions throughout the stages. In some cases it is seen that certain genera are only found in a single stage; in others they prevail in two stages; in others in three or more; but, save in rare and exceptional cases, when they prevail in two or more stages, these stages are in regular geological succession. This persistence of the genera is a very important geological and palæontological fact. The exceptions to it do not exceed 3 per cent. of the entire number of fossil genera, and may, therefore, be regarded as arising from some accidental cause.

551. This peculiar distribution of generic forms of the fossils, supplies to the geologist most useful stratigraphical tests. Thus, if a genus known to exist only in one peculiar geological stage, be found in any part of the crust of the earth whose structure has not been previously well ascertained, its presence may be taken as a certain indication of the character and position of the stage in which it is deposited.

The Contemporaneous Age.

HUMAN PERIOD.

552. The disruption of the earth's crust, extending W. 16° S., and E. 16° N., through which the chain of the great Alps was

forced up to its present elevation (220), which, according to M. D'Orbigny, was simultaneous with that which forced up the Chilian Andes, a chain which extends over a length of 3000 miles of the Western Continent, terminated the Tertiary age, and preceded immediately the creation of the human race and its concomitant tribes. The waters of the seas and oceans, lifted from their beds by this immense perturbation, swept over the continents with irresistible force, destroying instantaneously the entire fauna and flora of the last Tertiary period, and burying its ruins in the sedimentary deposits which ensued.

553. By this dislocation, Europe underwent a complete change of form. Among the most remarkable effects were the separation of the British Isles from the mainland by the subsidence of the land between Brittany and Normandy on the one side, and Cornwall and Devon on the other, and the consequent irruption of the sea. The Mediterranean, separated from the ocean, enlarged its limits by submerging a tract south of Marseille, which had remained dry since the commencement of the Tertiary age. Europe in general took its present form and relief, with the exception of some alluvial tracts, which at a more recent period were raised above the waters, either by the disruption which produced the system of Tænarus (221) and raised Etna, Vesuvius, and Santorini, or by other local disturbances of less importance, such as partial earthquakes.

554. Secondary effects followed, which have left their traces on every part of the earth's surface. Rivers of immense magnitude poured their streams from all the elevated summits over the subjacent plains, spreading out from point to point of their course into extensive lakes, on the bottoms of which they deposited those alluvial strata of which so many examples are presented in the valleys, plains, and provinces of all the great continents. In Europe such deposits are seen in the valleys of the Rhine, the Rhone, and other great rivers, on the great plain of Crau, in the south of France, having an extent of fifty square leagues, on the plain of Bavaria, and that which spreads itself out at the foot of the Alps over the state of Lombardy and Venice.

555. When the seas had settled into their new beds, and the outlines of the land were permanently defined, the latest and greatest act of creation was accomplished by clothing the earth with the vegetation which now covers it, peopling the land and water with the animal tribes which now exist, and calling into being the human race, appointed to preside over all living things, and to manifest the glory of the Creator by the development of attributes so exalted, as to be described by the inspired author of Genesis as rendering man in a certain sense the image of his Maker.

556. To convey an approximate estimate of this fauna, we have collected and arranged, from the data supplied by M. D'Orbigny, in the following table a synopsis of the total number of generic forms of each class.

Synopsis of the generic forms included in all the fauna (exclusive of the Annulata), from the first animalisation of the earth to the human period inclusively.

	Total number, living and fossil.	LIVING.			FOSSIL.		
		Created.	Revived.	Total.	Extinct.	Living.	Total.
Mammifers	279	164	47	211	68	47	115
Birds	300	256	38	294	6	38	44
Reptiles	200	133	13	146	54	13	67
Fishes	638	360	79	439	199	79	278
Crustacea	268	168	32	200	68	32	100
Cephalopods, acetabuliferous	33	15	5	20	13	5	18
,, tentaculiferous	36	..	1	1	35	1	36
Gastropods, terrestrial and fluviatile	22	5	16	21	1	16	17
,, marine	146	25	90	115	31	90	121
Lamellibranchia, fluviatile	11	6	5	11	..	5	5
,, marine	101	9	67	76	25	67	92
Brachiopods	41	..	9	9	32	9	41
Bryozoa	87	18	21	39	48	21	69
Echinodermata, echinoids	92	21	22	43	49	22	71
,, crinoids	59	1	2	3	56	2	58
,, asteroids	20	14	3	17	3	3	6
,, ophiuroids	20	10	1	11	9	1	10
Zoophytes	309	93	38	131	178	38	216
Foraminifera	87	14	50	64	23	50	73
Amorphozoa, testaceous	36	1	..	1	35	..	35
,, corneous	15	14	1	15	..	1	1
	2800	1327	540	1867	933	540	1473

557. It appears from this, that so far as observation has supplied data for such an estimate, the total number of generic animal forms which have been called into being, since the first animalisation of the earth to the present time, has been 2800. Of this number, 1327, or nearly the half, were created at the commencement of the human period, a large proportion for one period out of thirty. It must be observed, however, that it is extremely improbable that the number of genera in past periods is as well ascertained as in the present. In the one case we have the living creation to count from; in the other we have nothing but the buried remains of the fauna of each period.

Of the number of genera, 1473, that lived in previous ages, only 540 have reappeared. There are therefore 933 generic forms unknown to the present fauna. These, as we have seen, however,

were not simultaneously extinguished, a certain number disappearing for ever at the close of each period.

558. The specific forms are far more numerous, and not so exactly ascertained. Those of fossil Mollusca and Radiata have been elaborately described and catalogued by M. D'Orbigny, who, as we have already stated, has shown that each successive period had its own assemblage of species. In the following table, compiled from the Prodrome de Paléontologie of that eminent naturalist, we have given a synopsis of the distribution of species in the successive ages and periods.

Table showing the number of species of Mollusca and Radiata by the fossil remains that have lived during the successive geological epochs and periods.

		Number of Species.	
TERTIARY AGE.	Fifth period	606	
	Third and fourth period	3182	
	Second period	1576	6042
	First ,,	678	
CRETACEOUS AGE.	Seventh period	66	
	Sixth ,,	1579	
	Fifth ,,	380	
	Fourth ,,	849	4291
	Third ,,	410	
	Second ,,	156	
	First ,,	851	
JURASSIC AGE.	Tenth period	60	
	Ninth ,,	199	
	Eighth ,,	655	
	Seventh ,,	739	
	Sixth ,,	281	3846
	Fifth ,,	546	
	Fourth ,,	603	
	Third ,,	288	
	Second ,,	301	
	First ,,	174	
TRIASSIC AGE.	Second period	792	927
	First ,,	135	
PALÆOZOIC AGE.	Fifth period	91	
	Fourth ,,	1047	
	Third ,,	1198	3130
	Second ,,	418	
	First ,,	426	
	Total	18286	18286

559. Since the date of the publication of this table, the number of ascertained species of fossil Mollusca and Radiata has been increased by further discovery, and now amounts to 21000, to which 3000 fossil species of Vertebrata and Annulata being added, gives a total number of fossil specific forms, amounting to 24000.

560. The most conspicuous condition which distinguishes the

present from all past periods, is the existence of the human race among its fauna, the attributes of which are so peculiar as to place it out of all analogy with the other classes of animals.

561. Another striking physical difference between the present and all former periods, consists in the different divisions of the earth's surface into climatological zones, each zone having its peculiar fauna and flora. In all former ages and periods, including those which immediately preceded the present, no traces of climatic distinctions have been found. It has been already shown that the fossil fauna and flora of latitudes the most different, are analogous to the fauna and flora of warm climates. Now since this uniform temperature can only be ascribed to the great predominance of the effects of the central heat of the earth over those of solar radiation, it might naturally be supposed that the change would have been gradual, and that as the surface of the earth would have cooled down by degrees, climates would have been gradually manifested, the first differing but slightly in temperature, and then from period to period the difference increasing, until at length the earth would arrive at its present condition, exhibiting the extremes and means of the torrid temperate, and frigid zones.

Observation nevertheless has not as yet supplied any facts to confirm such theoretical views. On the contrary, in the fifth Tertiary period, which immediately preceded the present epoch, it is certain that the higher latitudes had a climate similar to that which now prevails towards the Line. Plants, now limited to southern latitudes, flourished in Europe. The palms, for example, which vegetated there, have completely disappeared, having retired to warmer regions. The elephant, rhinoceros, panther, and other tropical animals which abounded in high latitudes, have also wholly disappeared there, and are limited to those latitudes where a temperature prevails conformable to their organisation. The bear still lives in Europe, but not the species which is found entombed in the strata.

562. To render the fossil fauna compatible with the existence of isothermal lines, it has been supposed that the remains of animals and plants, peculiar to warm climates, which are deposited in the strata of high latitudes, may have been transported there by ocean currents. That such an hypothesis is inadequate and inadmissible, is demonstrated by the universality of the tropical fauna of all periods. The remains, especially of land animals and vegetables, which could by any possibility have been transported by such means, must necessarily have been few and local, and would appear merely as exceptions and anomalies among the fauna and flora proper to the climatic loca-

lity. No such condition of fossil deposits, however, is observed, those of the highest latitudes being as decidedly tropical as those of the lowest.

563. The formation of downs, littoral deposits, the filling up of lagoons, and the conversion of deltas into tracts of land, are severally contemporaneous geological phenomena, which serve, by the rate of their progress, and by their cumulative effects, as a sort of natural chronometers, by which the age of the human race, and its contemporary fauna, may be approximately estimated; and it is as remarkable as it is satisfactory, that the results are in no degree of discordance with the dates of Creation supplied by chronology, based on tradition and revelation. By the general accordance of such facts, it appears that the present period has now continued for not more than six or seven thousand years.

564. After all that has been explained of the series of convulsions which terminated the succession of periods in the history of the earth, it will be evident that the Mosaic narrative of the Deluge contains nothing incompatible with that course of events, which may be said, without exaggeration, to have been of habitual occurrence on our planet. Whether the Deluge be identified with the catastrophe which produced the system of Tænarus or be ascribed to other convulsions, such as extensive earthquakes, is immaterial, so far as respects the mere credibility of the narrative. It is worthy of remark also, that the Mosaic narrative is in accordance with national tradition among various peoples.

565. As to the future, all inference must be based upon analogy with the past. During a succession of eight or nine and twenty periods, we have seen that creation after creation has taken place. Assemblage after assemblage of animated beings have peopled the earth, which has been clothed and re-clothed with vegetation for their well-being. Upon the close of period after period, it has pleased the Most High, in his inscrutable wisdom, to doom such animated worlds to sudden destruction, attaining His purpose by the secondary agency of geological convulsions. The existing animated world presents nothing which can take it out of the category of the past, or exempt it from the ultimate fate which an inexorable law has prescribed to all former creations. The earth is still subject to the same local oscillations of its crust, whether continual and gradual, or violent and sudden, as heretofore. Volcanic phenomena declare, in unequivocal language, that the heavings of the internal fluid and incandescent matter have lost none of their terrific energy. Not only, therefore, does nothing justify the supposition that the convulsion which raised the chain of the great Alps, and destroyed the fauna and flora of the fifth

Tertiary period, was the last to which the earth would be subjected, but every probability, based upon analogy to the past, points to the very opposite conclusion. When we affirm, therefore, that a moment must arrive when what we call the present world will be destroyed; when man, and all his monuments, will be involved in one common destruction, when

> "The cloud-capt towers, the gorgeous palaces,
> The solemn temples, the great globe itself,
> Yea, all that it inherits shall dissolve;
> And, like an unsubstantial pageant faded,
> Leave not a rack behind,"

we declare no more than all the analogies of the past history of the Earth confirm.

But such finality will not, as Shakspeare implies, involve the "great globe itself." The law of periodicity which characterises in a manner so remarkable all the other phenomena of nature, reappears in the acts of creation itself, and pronounces in terms not to be misunderstood the future fate of the present tenants of the earth, and shadows forth its future destination. The convulsion which will sweep away man and his works, and the tribes of animals and vegetables created for his use, and will entomb their remains, will be followed by a calm of nature, after which, if we are to trust in the permanency of the play of those creative laws which have hitherto characterised the operations of Divine power, a new assemblage of organised beings will be called into life, and a new flora will clothe the earth. Intelligences will preside over this new world with faculties as much exalted above those with which man in all his pride is endowed, as the understanding of man himself is above that of the apes, monkeys, and baboons which were at the head of the population of the last period of the Tertiary age.

566. The short account of the Creation given in the first chapter of Genesis is in accordance with the results of geological discovery, in as complete a manner as would be possible in so brief a summary, destined, not to instruct the world in geology, but, without violating truth, to convey a general notion of the work of Omnipotence in the process of creation. Light was first created, that is, the universally diffused ether, by whose properties not only light, but heat and probably electricity and magnetism, if not gravity itself, severally exist. The firmament was next made, that is, space and the stars in countless numbers which occupy it, each of which is a centre of attraction to a group of surrounding bodies, and among these stars the sun.

567. According to Genesis, the organic creation was produced in four successive intervals of time, figuratively called Days, as

we now apply that term to any period during which a certain succession of phenomena are manifested. Thus we speak of the morning and the evening of life.

> "'Tis the sunset of life gives me mystical lore,
> For coming events cast their shadows before."

568. The first epoch was preceded by the formation of the outlines of land and water. The rupture of the incipient crust of the earth, as already explained (100), by throwing the solid surface into different levels, divided the earth into oceans, seas, continents, and islands. This is stated briefly but distinctly enough in Gen. i. 9, 10: "And God said, Let the waters under the heaven be gathered together unto one place, and let the dry land appear, and it was so. And God called the dry land Earth, and the gathering of the waters called he Seas: and God saw that it was good."

569. The surface of the land was now clothed with vegetation. Verses 11, 12: "And God said, Let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruit after his kind, whose seed is in itself, upon the earth: and it was so. And the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind: and God saw that it was good."

570. The second epoch of organic creation was signalised by the production of animal life in its lowest forms, being limited to marine tribes included under the general and familiar name of Fishes. Verse 20: "And God said, Let the waters bring forth abundantly after their kind." This was succeeded by the creation of Birds: "And every winged fowl after his kind: and God saw that it was good. And God blessed them, saying, Be fruitful, and multiply, and fill the waters in the seas, and let fowl multiply in the earth."

571. In complete accordance with this account geological researches show, that in the stages which immediately rest upon the azoic formation beds of coal are found, proving that the first land was clothed with vegetation. The animal remains found in the same deposits, consist almost exclusively of marine tribes. Some foot-tracks of birds, as we have shown, are also found in these formations. No traces of land animals yet appear. Thus in accordance with Genesis, geology announces that the first acts of creation were the production of "the grass, the herb yielding seed, and the tree yielding fruit after its kind," and that then the Creator caused the "waters to bring forth abundantly after their kind," and called into existence every winged fowl after its kind.

572. The third epoch of creation was signalised by the production of Mammifers and of land animals generally (ver. 24): "And God said, Let the earth bring forth the living creature after his kind, cattle, and creeping thing, and beast of the earth after his kind: and it was so. And God made the beast of the earth after his kind, and cattle after their kind, and every thing that creepeth upon the earth after his kind: and God saw that it was good."

573. The later geological ages, and especially the Tertiary, are here indicated, in which, as has been shown, the tribes mentioned in this short and popular statement were created.

574. The fourth, last, and latest great act of Omnipotence was the creation of the human race. On the last day or epoch of creation, "God said, Let us make man in our own image, after our likeness: and let them have dominion over the fish of the sea, and over the fowl of the air, and over the cattle of the field, and over all the earth, and over every creeping thing that creepeth upon the earth. So God created man in his own image, in the image of God created he him; male and female created he them."

575. It is perhaps in this last part of the Mosaic narrative that the most striking and interesting accordance with geological science is observable. According to Genesis, the last epoch of creation was exclusively given to the creation of the human race. Naturalists have reduced animal forms to seventy-eight orders, in one of which man stands alone. It appears from the researches of palæontologists that of these seventy-eight, all but one,—that including man,—were created before the close of the Tertiary period, and that in the creation which followed that period, man was the only animal order added to those of former creations.

576. I have thought it right to develope these points at some length, inasmuch as many consciences have felt alarm at the supposed discordance between Scriptural history and geological discovery. It will, however, be seen, from what I have here stated, that not only no such discordance exists, but that making such allowances for the latitude of language, as are indispensable in the interpretation of so brief and popular a description, designed not for the scientific but for the mass of mankind, as that given in Genesis, there is the most remarkable and satisfactory accordance with natural phenomena.

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